

COURSES OF STUDY FOR POSTGRADUATE PROGRAMMES

(2025 – 2027)



**Defence Institute of Advanced Technology
(Deemed to be University)
Pune – 411025**

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PREFACE

This book gives comprehensive information on the structure, curriculum and syllabus of various Post Graduate programmes. The Board of Studies and Academic Council Continuously monitor these Courses and make appropriate modifications / improvements from time to time.

In order to keep pace with the rapid developments in science and technology and also to keep in view the requirements of the nation and the aspirations of students, it is imperative that the academic programmes of the institute are reviewed continuously.

The academic system is semester based and hence the students are required to follow certain procedures and meet certain academic requirement each semester. The academic performance is monitored by Postgraduate Graduate Committee (PGC), which also reviews status of individuals after reviewing their performance.

The advisory system plays a very important role in a flexible curriculum of the type offered under the various programmes of the Institute. The choice of courses being very wide and considerable flexibility in the programme being its characteristic feature, students normally need guidance to formulate a meaningful and well-knit programme for each of them.

Academic Calendar

Academic Calendar 2025-26

S.No.	Activity		Autumn (Odd Semester)	Spring (Even Semester)
1	Registration (MTech/MS by research/MSc/PGD/PhD) Add/Drop Courses & Finalizing Electives and Orientation Programme	Newly admitted PG Students (1 st Year)	1 st Aug – 18 th Aug 2025	05 th Jan - 16 th Jan 2026
		All other students	14 th July – 25 th July 2025	
2	PhD Progress review by DRMC		14 th July – 31 st July 2025	12 th Jan – 30 th Jan 2026
3	Sport/Cultural/NSS/Other student-related activities			12 th Jan 2026-18 th Jan 2026
4	Project work/Dissertation (for 2 nd year)		14 th July – 21 th Nov 2025 (19 weeks)	22 nd Dec 2025 – 01 st May 2026 (19 weeks)
5	Commencement of Classes including Preparation	2 nd Year PG Students & Ph.D. Scholars	21 th July 2025-5 th Dec 2025	12 th Jan 2026 – 22 nd May 2026 (19 weeks)
		Newly admitted PG Students (1 st year) 2025-2027 batch	07 th Aug 2025-12 th Dec 2025 (19 weeks)	
6	Last Date of Late Registration with late fee		29 th Aug 2025	30 th Jan 2026
7	Sending the Panel of Examiners to CoE		08 th Sep 2025	03 rd Mar 2026
8	Last date of submission of Examination form and Admit Card to CoE by respective Departments/Schools & MSc OJT certified Marksheet/Grade to CoE		10 th Sep 2025	04 th Mar 2026
9	Sending Certified list of courses (Regular Self stud audit etc) registered by the students by Jt.Reg. (AC) to COE		18 th Sep 2025	06 th Mar 2026
10	Assessment I *		22 nd Sep -27 th Sep 2025	09 th Mar – 14 th Mar 2026

11	Oral Examination Committee approved by Vice Chancellor to be sent to COE – Phase I Thesis evaluation/ Phase II Final Thesis Evaluation/MSc Project		12 th Nov 2025	24 th Apr 2026
12	Assessment II *		24 th Nov -28 th Nov 2025	04 th May – 8 th May 2026
13	Phase I Thesis evaluation/ Phase II Final Thesis evaluation (MTech/MSc)		24 th Nov – 03 rd Dec 2025	04 th May – 13 th May 2026
14	End Semester Examination *	Lab Exams (without affecting classwork) & Backlog- Examination	08 th Dec – 12 th Dec 2025	18 th May – 22 nd May 2026
		Theory Exams All 2nd Year students & PhD	08 th Dec -12 th Dec 2025	25 th May – 5 th June 2026
		Theory Exam Newly admitted PG Students (1st year) & Phd	15 th Dec – 24 th Dec 2025	
15	Skill Development Programme/Workshops/II C Activities as per NEP 2020		25 th Dec 2025 – 11 th Jan 2026	-----
16	Last date for submission of certified statement of Marks to COE (Courses/Seminar/Lab/Th esis)		29 th Dec 2025	10 th June 2026
17	Winter/Summer Vacation for Faculty		29 th Dec 2025 - 11 th Jan2026 (2 weeks)	15 th June – 12 th July 2026 (4 weeks)
18	Result Declaration		02 nd Jan 2026	12 th June 2026
19	Outstation Instructional Tour (Optional)		During the period provided for classes without affecting any academic activities	

*Assessments & End Semester Examinations will be conducted by CoE.

Programmes Structure & Syllabus of Courses

*Department of Aerospace
Engineering & Autonomous
Systems*

Department of Aerospace Engineering & Autonomous Systems

The Department of Aerospace Engineering & Autonomous Systems is committed to academic excellence, cutting-edge research, and indigenous technology development in the fields of aerospace engineering and autonomous systems. The department offers specialized *M. Tech. programs in Aerospace Engineering (Guided Missiles), Aerospace Engineering (UAVs), Automation & Robotics, and Industrial Systems Engineering (Model Based Systems Engineering)*, designed to meet the growing needs of defense, space, and industrial sectors. These programs aim to nurture highly skilled professionals with strong technical foundations, interdisciplinary expertise, and the ability to innovate in strategically important domains.

Vision: To be a center of excellence in Aerospace Engineering and Autonomous Systems, fostering innovation, research, and technological leadership to address national strategic needs and global challenges in aerospace and intelligent autonomous technologies.

Mission: To impart high-quality education and training in Aerospace Engineering and Autonomous Systems, preparing skilled professionals and researchers through interdisciplinary learning and advanced research, while fostering innovation to address real-world challenges across strategic sectors with academic rigor and ethical excellence. The department is also committed to strengthening collaborations with academia, R&D organizations, defense establishments, and industry to achieve superior outcomes and drive technological advancement.

Research Areas:

- Shock Wave - Boundary Layer interaction & control
- Aerodynamic Analysis of Grid Fins
- Aero-Thermodynamics
- Flow Control Techniques
- Aerodynamics studies on MAVs
- Hypersonic Aerodynamics
- UAV/ Aircraft Design
- Flight Guidance & Control
- UAV Swarms
- Aircraft System Identification and Parameter Estimation

- Linear and Nonlinear Control of Aircrafts
- Path planning of UAVs
- Aeroelasticity
- AI/ML for Aerospace Engineering

M. Tech. in Aerospace Engineering (Guided Missiles)

Brief Description: The department has been involved in conducting post-graduate program in Aerospace Engineering with specialization in Guided Missiles. This program includes courses covering core areas of aerospace engineering, with a focus on technologies relevant to guided missiles. The curriculum of the program has been designed to meet the needs of the Tri-services, Defence R&D Organizations, Public Sector Undertakings involved in missile technologies, as well as students with a keen interest in the study of missiles.

Eligibility: B.E./B.Tech. degree in Aerospace / Aeronautical / Mechanical/ Electrical/ Electronics/ Electronics and Communication / Production* / Computer Science & Engineering* from recognized university.

*for Tri-services/DRDO officers only

Organization: The program spans four semesters. In the first semester, students undertake five core courses, one professional elective, and a course in research methodology. The second semester includes two core courses, three electives, one laboratory course, and one skill-based course. The third and fourth semesters are entirely dedicated to dissertation work. Each course comprises two continuous assessments of 20 marks each, an end-semester examination of 50 marks, and assignments/quizzes carrying 10 marks. The dissertation is evaluated twice—once at the end of the third semester, and at the end of the fourth semester upon submission of the report/thesis and a presentation before a committee comprising internal and external examiners. To enrich students' understanding and appreciation of the subject, visits to various DRDO laboratories, national research institutions, and relevant industries are incorporated into the program.

M. Tech. in Aerospace Engineering (Guided Missiles)

Semester I

Sl. No.	Course Code	Course	Contact Hours Per Week		Total Credits
			L	T/P	
1	AE 601	Aerospace Propulsion	3	0	3
2	AE 602	Aerodynamics	3	0	3
3	AE 603	Navigation, Guidance & Control	3	0	3
4	AE 604	Aerospace Structures	3	0	3
5	AE 605	Flight Mechanics	3	0	3
6		Professional Elective I	3	0	3
7	PGC 601	Research Methodology & IPR	2	0	2
		Total	20	0	20

Semester II

Sl. No.	Course Code	Course	Contact Hours Per Week		Total Credits
			L	T/P	
1	AE 606	Flight Instrumentation	3	0	3
2	AE 607	Missile Design	3	0	3
3		Professional Elective – II*	3	0	3
4		Professional Elective – III	3	0	3
5		Professional Elective – IV	3	0	3
6	AE 641	Aerospace Engineering Lab	0	6	3
7	PGC 602	(Personality Development and Communication Skills Modules)	2	0	2
		Total	17	6	20

**Student have to choose at least one subject from the list of Domain Specific Electives*

Semester III

Sl. No.	Course Code	Course	Contact Hours Per Week		Total Credits
			L	T/P	
3	AE 651	M. Tech. Dissertation & Seminar Phase I	40		20
		Total	40		20

Semester IV

Sl. No.	Course Code	Course	Contact Hours Per Week		Total Credits
			L	P	
1	AE 652	M.Tech. Dissertation & Seminar Phase II	40		20
		Total	40		20

List of Professional Electives

Sl. No.	Course Code	Course
		Domain Specific Electives
1	AE 608	Missile Propulsion
2	AE 609	Missile Aerodynamics
3	AE 610	Missile Guidance & Control
4	AE 611	Missile Structures
5		MOOC/SWAYAM-NPTEL [#]
		Other Electives
6	AE 612	UAV/Aircraft Design
7	AE 613	UAV Propulsion
8	AE 614	UAV Aerodynamics
9	AE 615	UAV Guidance & Control
10	AE 616	UAV Structures
11	AE 617	Nonlinear and Robust Control
12	AE 618	Avionics
13	AE 619	Structural Dynamics and Aero-elasticity
14	AE 620	Experimental Aerodynamics
15	AE 621	Experimental Methods in Fluid Mechanics
16	AE 622	Computational Aerodynamics
17	AE 623	Hypersonic Aerodynamics
18	AE 624	Aircraft Assembly, Inspection & Tests
19		MOOC/SWAYAM-NPTEL [#]
20		Core / Professional Electives from other Departments
[#] Maximum of 6 credits can be opted by students as Professional Electives from the list of online courses on NPTEL/SWAYAM during I & II semester.		

M. Tech. in Aerospace Engineering (UAVs)

Brief Description: The program was initiated in 2016 and offers courses in various areas of aerospace engineering with a focus on Unmanned Aerial Vehicles (UAVs). The curriculum has been designed to address the specific requirements of the tri-services, Defence R&D organizations, public sector undertakings, and industries involved in UAVs and related technologies.

Eligibility: B.E./B. Tech. degree in Aerospace / Aeronautical / Mechanical/ Electrical/ Electronics/ Electronics and Communication / Production* / Computer Science & Engineering* from recognized university.

*for Tri-services/DRDO officers only

Organization: The program spans four semesters. In the first semester, students undertake five core courses, one professional elective, and a course in research methodology. The second semester includes two core courses, three electives, one laboratory course, and one skill-based course. The third and fourth semesters are entirely dedicated to dissertation work. Each course comprises two continuous assessments of 20 marks each, an end-semester examination of 50 marks, and assignments/quizzes carrying 10 marks. The dissertation is evaluated twice—once at the end of the third semester, and at the end of the fourth semester upon submission of the report/thesis and a presentation before a committee comprising internal and external examiners. To enrich students' understanding and appreciation of the subject, visits to various DRDO laboratories, national research institutions, and relevant industries are incorporated into the program.

M. Tech. in Aerospace Engineering (UAVs)

Semester I

Sl. No.	Course Code	Course	Contact Hours Per Week		Total Credits
			L	T/P	
1	AE 601	Aerospace Propulsion	3	0	3
2	AE 602	Aerodynamics	3	0	3
3	AE 603	Navigation, Guidance & Control	3	0	3
4	AE 604	Aerospace Structures	3	0	3
5	AE 605	Flight Mechanics	3	0	3
6		Professional Elective I	3	0	3
7	PGC 601	Research Methodology & IPR	2	0	2
		Total	20	0	20

Semester II

Sl. No.	Course Code	Course	Contact Hours Per Week		Total Credits
			L	T/P	
1	AE 606	Flight Instrumentation	3	0	3
2	AE 612	UAV/Aircraft Design	3	0	3
3		Professional Elective – II*	3	0	3
4		Professional Elective – III	3	0	3
5		Professional Elective – IV	3	0	3
6	AE 641	Aerospace Engineering Lab	0	6	3
7	PGC 602	(Personality Development and Communication Skills Modules)	2	0	2
		Total	17	6	20

**Students have to choose at least one subject from the list of Domain Specific Electives*

Semester III

Sl. No.	Course Code	Course	Contact Hours Per Week		Total Credits
			L	T/P	
3	AE 651	M. Tech. Dissertation & Seminar Phase I	40		20
		Total	40		20

Semester IV

Sl. No.	Course Code	Course	Contact Hours Per Week		Total Credits
			L	T/P	
1	AE 652	M.Tech. Dissertation & Seminar Phase II	40		
		Total	40		

1 Credit in Lecture/Tutorial means 1 contact hour and 1 credit practice/Project Thesis means 2 contact hours in a week.

List of Electives

Sl. No.	Course Code	Course
		Domain Specific Electives
1	AE 613	UAV Propulsion
2	AE 614	UAV Aerodynamics
3	AE 615	UAV Guidance & Control
4	AE 616	UAV Structures
5		MOOC/SWAYAM-NPTEL [#]
		Other Electives
6	AE 607	Missile Design
7	AE 608	Missile Propulsion
8	AE 609	Missile Aerodynamics
9	AE 610	Missile Guidance & Control
10	AE 611	Missile Structures
11	AE 617	Nonlinear and Robust Control
12	AE 618	Avionics
13	AE 619	Structural Dynamics and Aero-elasticity
14	AE 620	Experimental Aerodynamics
15	AE 621	Experimental Methods in Fluid Mechanics
16	AE 622	Computational Aerodynamics
17	AE 623	Hypersonic Aerodynamics
18	AE 624	Aircraft Assembly, Inspection & Tests
19		Core / Professional Electives from other Departments
20		MOOC/SWAYAM-NPTEL [#]
[#] Maximum of 6 credits can be opted by students as Professional Electives from the list of online courses on NPTEL/SWAYAM during I & II semester.		

Syllabus

Course Code	Course Name	L – T – P	Credits
AE 601	Aerospace Propulsion	3 – 0 – 0	3
Course Objectives: • To classify and differentiate various aerospace propulsion systems • To apply conservation laws and thermodynamic principles to propulsion systems • To analyze the performance parameters of propulsion systems • To understand the configuration and operation of air-breathing engines • To study propulsion in supersonic regimes • To comprehend the design and functioning of rocket propulsion systems • To examine propulsion systems in missile applications • To study propulsion technologies specific to UAVs			
Unit I: Fundamentals of Propulsion Types of propulsion systems: air-breathing and non-air-breathing; Conservation laws applied to propulsion systems; Propulsion performance parameters: thrust, specific impulse, propulsive efficiency, thermal efficiency; Review of thermodynamic cycles (Brayton and ideal rocket cycle).			
Unit II: Air-Breathing Engines – Jet Propulsion Types: turbojet, turbofan, turboprop, and turboshaft; Thrust equation, TSFC, efficiencies; Component-wise study: diffuser, compressor, combustor, turbine, and nozzle; Performance estimation of ideal and real engines.			
Unit III: Supersonic and Ramjet Propulsion Ramjet and scramjet engines: working principles; Supersonic intakes and shock structures; Thermal choking and combustion in supersonic flows; Applications in high-speed aircraft and missiles.			
Unit IV: Rocket Propulsion Classification: solid, liquid, hybrid; Rocket thrust equation and specific impulse; Rocket motor components and performance; Introduction to multi-stage rockets and mass ratio; Introduction to combustion instability and nozzle design.			
Unit V: Missile Propulsion Systems Overview of missile classifications based on range and propulsion; Solid rocket motors: grain design, burn rate, case design; Liquid and hybrid propulsion in missiles; Thrust vector control and propulsion integration in tactical systems; Case examples: Akash, Agni, BrahMos (overview only).			
Unit VI: UAV Propulsion Systems UAV classification and propulsion needs; Electric propulsion Electric Motors, Solar Cells, Advanced Batteries, Fuel Cells; Propellers: Classical Momentum Theory, Blade Element Theory, Variable Speed Propeller, Propeller Charts, Performance Selection & Matching, Ducted Propellers; IC engines for UAVs: two-stroke and four-stroke characteristics; Micro turbojet and turbofan engines in UAVs.			

Course Outcomes
After completing this course, the students will be able to: CO1: Classify and compare various aerospace propulsion systems CO2: Analyze and evaluate the performance of gas turbine engines CO3: Explain the working principles and thermodynamic challenges of ramjet and scramjet propulsion systems CO4: Demonstrate understanding of rocket propulsion systems CO5: Interpret propulsion system requirements for missile applications CO6: Identify and select appropriate propulsion systems for UAVs
Text Books
1. Saeed Farokhi, <i>Aircraft Propulsion</i>, 2nd Edition, Wiley, 2009. 2. Jack L. Kerrebrock, <i>Aircraft Engines and Gas Turbines</i>, 2nd Edition, MIT Press, 1992. 3. Jack D. Mattingly and Hans von Ohain, <i>Elements of Propulsion: Gas Turbines and Rockets</i>, AIAA Education Series, 2006. 4. Philip Hill and Carl Peterson, <i>Mechanics and Thermodynamics of Propulsion</i>, 2nd Edition, Prentice Hall, 1992. 5. George P. Sutton and Oscar Biblarz, <i>Rocket Propulsion Elements</i>, 9th Edition, Wiley, 2016.
Reference Books
1. Gordon C. Oates, <i>Aerothermodynamics of Gas Turbine and Rocket Propulsion</i>, 3rd Edition, AIAA Education, 1997. 2. Maurice J. Zucrow, <i>Aircraft and Missile Propulsion</i>, Vol. 1 & 2, Wiley, 1958.

Course Code	Course Name	L – T – P	Credits
AE 602	Aerodynamics	3 – 0 – 0	3
Course Objectives: • To introduce the foundational principles and governing equations of aerodynamics • To develop a strong conceptual understanding of incompressible flow over airfoils and wings • To explain the physics of viscous flow phenomena including boundary layers, turbulence, and flow separation • To analyze compressible flow and shock wave phenomena • To introduce hypersonic flow regimes and shock wave–boundary layer interactions • To understand theories and principles specific to missile configuration • To explore aerodynamic requirements and challenges in UAV design • To introduce modern computational and experimental methods in aerodynamics			
Unit I : Introduction to Aerodynamics Role of aerodynamics in aerospace systems; Classification of flows: incompressible vs. compressible, viscous vs. inviscid; Governing equations, RTT; Flow kinematics, Elementary flows, Non-lifting and lifting flows; Basic aerodynamic forces and moments: lift, drag, pitching moment; Non-dimensional parameters: Reynolds number, Mach number, Lift and Drag coefficients;			

Unit II: Incompressible Flow over Airfoils and Wings

Airfoil nomenclature and characteristics; Flow over airfoils; Kutta-Joukowski theorem, Kutta condition, Kelvin's theorem, Thin airfoil theory; Flow over wings; Prandtl's lifting line theory; Viscous fluid flow, Turbulent flow, flow separation, Boundary layer.

Unit III: Compressible Flows and Shock Waves

Governing equations for compressible fluid flow; Normal shock waves, Oblique shock and expansion waves, Prandtl-Mayer waves, Shock-Expansion Theory. Flow over supersonic airfoils and wings; Shock Wave – Boundary Layer interactions, Introduction to Hypersonic flows

Unit IV: Missile Aerodynamics

Missile configurations and aerodynamic considerations; Flow over slender bodies of revolution; Aerodynamic forces during different flight phases (launch, cruise, terminal); Control surfaces and maneuvering characteristics; Low Aspect Ratio Wings, Intake Aerodynamics, Store Separation Aerodynamics.

Unit V: UAV Aerodynamics

Overview of UAV types and missions; Aerodynamic requirements of low-speed and high-altitude UAVs; Low Reynolds number aerodynamics.

Unit VI: Computational & Experimental Aerodynamics

Computational & Experimental Methods for Prediction of Aerodynamic Characteristics

Course Outcomes

After completing this course, the students will be able to:

CO1: Understand and apply the fundamental principles of aerodynamics.

CO2: Analyze incompressible flow over airfoils and wings.

CO3: Evaluate compressible flow phenomena such as shock waves, expansion waves, and their influence on aerodynamic performance in supersonic and hypersonic regimes.

CO4: Apply aerodynamic principles to missile configurations, analyzing forces during different flight phases, maneuverability, and control surface behavior.

CO5: Assess aerodynamic characteristics and design considerations of UAVs, especially in low-speed and low Reynolds number environments.

CO6: Demonstrate understanding of computational and experimental methods used for predicting and analyzing aerodynamic characteristics in aerospace systems.

Text Books

1. John D. Anderson, *Fundamentals of Aerodynamics*, 4th Edition, McGraw Hill, 2006.
2. Edward L. Houghton and Peter W. Carpenter, *Aerodynamics for Engineering Students*, 5th Edition, Butterworth-Heinemann, Oxford, 2003.
3. John D. Anderson, *Introduction to Flight*, 5th Edition, McGraw Hill, 2005.
4. Seng C. Chin, *Missile Configuration Design*, McGraw Hill, 1961.

Reference Books

1. Frank M. White, *Viscous Fluid Flow*, McGraw Hill, 2006.
2. Frank M. White, *Fluid Mechanics*, McGraw Hill, 2003.
3. Robert W. Fox and Alan T. McDonald, *Introduction to Fluid Mechanics*, 5th Edition, John Wiley & Sons, Inc., 2003.

4. John D. Anderson, *Modern Compressible Flow: With Historical Perspective*, 3rd Edition, McGraw Hill, 2004.
5. John D. Anderson, *Hypersonic and High Temperature Gas Dynamics*, McGraw Hill, 2006.
6. Maurice Rasmussen, *Hypersonic Flow*, John Wiley & Sons, Inc., 1994.
7. Michael R. Mendenhall, *Tactical Missile Aerodynamics*, 2nd Edition, AIAA Publications, 1992.
8. Reg Austin, *Unmanned Aircraft Systems: UAVs Design, Development and Deployment*, John Wiley & Sons, Inc., 2010.
9. Pijush K. Kundu and Ira M. Cohen, *Fluid Mechanics*, Elsevier, 2016.

Course Code	Course Name	L – T – P	Credits
AE 603	Navigation, Guidance and Control	3 – 0 – 0	3
Course Objectives: • To impart knowledge about the Navigation, Guidance and Control of aerospace vehicles. • To introduce the fundamental concepts of Radar, Navigation, Landing, Guidance Laws, and control system. • To enable the students to understand various types of control system tools to analyze the system operation and handling. • To introduce Missile & UAV control & Guidance.			
Unit I Navigation: Navigation systems and principles of operation, Continuous waves and frequency modulated radars, MTI and Doppler radars; types of navigation; ILS, Optical landing, VOR, INS, and GPS.			
Unit II Guidance: Classification and phases of missile guidance. Guidance laws: pursuit, LOS, CLOS, BR and PN laws. Advance Guidance Systems such as Imaging, Scene Correlation, Millimetric wave, Non-LOS Guidance Systems, Laser Based Guidance Systems.			
Unit III Control: Classical linear time invariant control systems, transfer function representations, stability, Time domain characteristics, Frequency domain characteristics, Root Locus, Nyquist and Bode plots, Introduction to state space analysis.			
Unit IV Missile Control & Guidance: Missile Dynamics and Control Challenges; Missile Autopilot Systems; Integrated Guidance and Control.			

Unit V UAV Control & Guidance: Flight Dynamics of UAVs; UAV Guidance Algorithms; UAV Autopilot Systems; Swarm and Cooperative Guidance.
Course Outcomes
After completing this course, the students will be able to: CO1: Learn the various types of radar and the navigation methods commonly used by the air vehicles. CO2: Learn about the unguided and guided missiles, and the various types of the guidance laws used in the interception of the targets. CO3: Learn about the concept of the LTI control system and solve stability and design problems using time-domain and frequency-domain tools. CO4: Design and analyze a control system to meet the specific requirements. CO5: Understand concepts of Missile & UAV control & guidance.
Text Books
1. Merill I. Skolnik, <i>Introduction to Radar Systems</i>, Tata McGraw Hill, New Delhi, 2001. 2. Myron Kayton and Walter R. Fried, <i>Avionics Navigation Systems</i>, John Wiley & Sons, 1997. 3. Paul Zarchan, <i>Tactical and Strategic Missile Guidance</i>, American Institute of Aeronautics and Astronautics, 2007. 4. George M. Siouris, <i>Missile Guidance and Control Systems</i>, Springer, 2004. 5. Katsuhiko Ogata, <i>Modern Control Engineering</i>, Prentice Hall of India, 1995.
Reference Books
1. John H. Blakelock, <i>Automatic Control of Aircraft and Missiles</i>, Wiley, 1991. 2. Anthony Lawrence, <i>Modern Inertial Technology</i>, Springer, 1998. 3. Ching-Fang Lin, <i>Modern Navigation, Guidance and Control Processing</i>, Prentice Hall, 1991. 4. Boris Friedland, <i>Control System Design: An Introduction to State-Space Methods</i>, McGraw-Hill, Singapore, 1987. 5. Albert Helfrick, <i>Principles of Avionics</i>, Avionics Communications, 2009.

Course Code	Course Name	L – T – P	Credits
AE 604	Aerospace Structures	3 – 0 – 0	3
Course Objectives: • To introduce the fundamentals of aerospace structural systems. • To develop the ability to analyze thin-walled structural elements. • To understand material behavior and failure criteria. • To provide knowledge on the design and analysis of major aerospace structural components. • To enable students to understand Missile & Aerospace Structures.			
Unit I: Introduction to Aerospace Structures Role and classification of aerospace structures: aircraft, missile, spacecraft, UAV; Types of loads and load paths: axial, bending, shear, torsion; Overview of structural materials: aluminum, titanium, composites; Structural design philosophy: weight minimization, safety factors, stiffness vs. strength.			
Unit II: Analysis of Thin-Walled Structures Bending of thin-walled beams and open/closed sections; Shear center and shear flow; Torsion of thin-walled sections; Semi-monocoque structures and load distribution; Structural idealization: booms, panels, and ribs.			
Unit III: Stress, Strain, and Structural Failure Stress-strain relationships for isotropic and anisotropic materials; Principal stresses, Mohr's circle; Failure theories: maximum stress, maximum strain, von Mises, Tsai-Hill (composite failure); Buckling of columns and plates; Vibration, Fatigue and fracture concepts (introductory).			
Unit IV: Structural Components and Their Design Design and analysis of wing spars, ribs, stringers, longerons; Fuselage structures: frames, bulkheads, skin; Landing gear loads and structural reinforcement; Joints: riveted, bolted, welded, bonded; Composite structure basics and sandwich panels.			
Unit V: Missile Structures Missile configuration and structural layout; High acceleration and dynamic loading considerations; Thermal and aerodynamic loadings during boost and re-entry; Material selection and structural integrity under launch conditions; Integration of warhead, propulsion, and guidance systems with structure; Case study: structural layout of tactical and strategic missiles.			
Unit VI: UAV Structures Structural requirements for small, medium, and HALE UAVs; Lightweight design for endurance and portability; Composite usage and modular design in UAV airframes; Wing-body integration and load transfer; Payload integration and vibration isolation; Case study: structural analysis of fixed-wing and rotary UAVs.			

Course Outcomes
After completing this course, the students will be able to: CO1: Identify and classify aerospace structural components and loading types CO2: Analyze thin-walled structural members CO3: Apply stress-strain relations and failure theories CO4: Design and evaluate structural components. CO5: Assess structural requirements and challenges specific to missile and UAV structures.
Text Books
1. David J. Peery, <i>Aircraft Structures</i>, Dover Publications, 2011. 2. Elmer F. Bruhn, <i>Analysis and Design of Flight Vehicle Structures</i>, S.R. Jacobs, 1973.
Reference Books
1. Timothy H. G. Megson, <i>Aircraft Structures for Engineering Students</i>, Butterworth-Heinemann, 2010. 2. George F. Titterton, <i>Aircraft Materials and Processes</i>, Himalayan Books, 2013.

Course Code	Course Name	L – T – P	Credits
AE 605	Flight Mechanics	3 – 0 – 0	3
Course Objectives: • To equip students with the ability to apply equations of motion • To introduce the basic principles of flight performance • To develop an understanding of aircraft stability and control • To provide an overview of missile flight mechanics • To explore the unique aspects of UAV flight mechanics			
Unit I: Flight Performance Standard Atmosphere. Aerodynamics of airfoils and wings. Brief history of flight. Introduction to performance. Equations of motion. Thrust required, thrust available & maximum velocity for level un-accelerated flight. Power required, power available and max. velocity. Altitude effects on power required and available. Rate of climb. Gliding Flight. Absolute ceiling. Time to climb. Range and Endurance. Takeoff and Landing performance. Turning Flight and v-n diagram.			
Unit II: Flight Stability and Control Definition of stability and control: static stability, dynamic stability, control, the partial derivative. Moments on missile, absolute angle of attack, Criteria for longitudinal static stability. Contribution of wings to moment about center of gravity, Contribution of tail to moment about center of gravity. Total pitching moment about center of gravity. Equations for longitudinal static stability. The neutral point. The static margin. Aerodynamic derivatives. Cross coupling. The concept of static longitudinal control. Lateral stability: Induced rolling moments, Various configurations. Aerodynamic damping. Stability margins. Control forces and moments.			
Unit III: Missile Flight Mechanics Types of missile trajectories: ballistic, cruise, and guided; Equations of motion for missile flight; Launch dynamics and boost phase mechanics; Control and guidance aspects; Stability			

and maneuvering of symmetric and asymmetric missiles; Gravity turn and terminal phase considerations. Emerging Trends.

Unit IV: UAV Flight Mechanics

UAV configurations: fixed-wing, rotary-wing, hybrid; Low-speed flight dynamics and control challenges; Effect of low Reynolds number on performance; Autonomous flight and autopilot basics; Flight envelope for small and medium UAVs; Energy efficiency and flight planning. Emerging Trends.

Course Outcomes

After completing this course, the students will be able to:

CO1: Analyze flight performance parameters

CO2: Evaluate static and dynamic stability criteria

CO3: Demonstrate an understanding of Missile flight mechanics

CO4: Demonstrate an understanding of UAV flight mechanics

CO5: Solve practical aerospace flight mechanics problems.

Text Books

1. Bernard Etkin, *Dynamics of Atmospheric Flight*, Dover, 2005.
2. Robert C. Nelson, *Flight Stability and Automatic Control*, Tata McGraw-Hill, New Delhi, 2007.
3. Bandu N. Pamadi, *Performance, Stability, Dynamics and Control of Airplanes*, AIAA Educational Series, 2004.
4. John D. Anderson Jr., *Introduction to Flight*, Tata McGraw-Hill, New Delhi, 2007.

Reference Books

1. Michael R. Mendenhall, *Tactical Missile Aerodynamics*, 2nd Edition, AIAA Publications, 1992.
2. Eugene L. Fleeman, *Missile Design and System Engineering*, AIAA Education Series, 2012.
3. James J. Jerger, *System Preliminary Design*, D. Van Nostrand Co., Inc., Princeton, New Jersey, 1960.
4. A. Everette Puckett and Simon Ramo, *Guided Missile Engineering*, McGraw Hill, 1989.
5. Marcello R. Napolitano, *Aircraft Dynamics: From Modelling to Simulation*, Wiley, 2012.

Course Code	Course Name	L – T – P	Credits
AE 606	Flight Instrumentation	3 – 0 – 0	3

Course Objectives:

- To introduce the basic concepts and importance of flight instrumentation systems.
- To provide knowledge of air data, inertial, and navigation sensors.
- To familiarize students with data acquisition, telemetry, and ground support systems.
- To develop an understanding of specialized instrumentation used in missiles.
- To explore lightweight, autonomous instrumentation solutions for UAVs

Unit I: Fundamentals of Flight Instrumentation

Introduction to flight instrumentation systems and their significance; Categories: Air data, inertial, navigation, engine, and environment instrumentation; Basics of measurement systems: sensors, signal conditioning, telemetry; Data acquisition systems (DAQ), analog vs. digital instrumentation; Calibration and error analysis.

Unit II: Air Data and Inertial Sensors

Pitot-static system: airspeed, Mach number, altitude measurement; Altimeters, vertical speed indicators, and barometric systems; Inertial sensors: accelerometers, gyroscopes, IMU (Inertial Measurement Unit); Attitude and heading reference systems (AHRS).

Unit III: Navigation and Positioning Instruments

GNSS/GPS receivers and satellite-based navigation; Doppler navigation, INS/GPS integration; Magnetic compasses, flux gate sensors; Terrain following and terrain referenced navigation (introductory).

Unit IV: Data Recording, Telemetry and Ground Systems

Onboard data acquisition and flight data recorders; Telemetry systems: RF links, modulation schemes, antennas; Real-time data visualization and ground control stations; Synchronization and time-stamping in flight testing; Health monitoring and fault detection.

Unit V: Missile Instrumentation

Instrumentation for guidance, navigation, and control; Accelerometers and rate gyros for high-g maneuvers; Telemetry and real-time tracking during missile flight; Sensor hardening for thermal and vibrational loads; Seeker and target tracking sensor overview (IR, radar-based—introductory).

Unit VI: UAV Instrumentation

Lightweight and power-efficient sensors for UAVs; Autopilot systems and sensor integration; Environmental sensors: wind, pressure, GPS, altitude; Ground control and telemetry links for UAV operation; Redundancy and reliability considerations for long-endurance UAVs.

Course Outcomes
After completing this course, the students will be able to: CO1: Explain the structure and classification of flight instrumentation systems CO2: Analyze the operation of air data and inertial sensors CO3: Apply knowledge of navigation systems and positioning instruments, CO4: Evaluate data acquisition and telemetry systems CO5: Assess the instrumentation requirements for missiles and UAVs
Text Books
1. Ernest O. Doebelin, <i>Measurement Systems: Application and Design</i>, 4th Edition, McGraw Hill International, New York, 1990. 2. Jacob Fraden, <i>Handbook of Modern Sensors</i>, Springer, 2016. 3. Robert P. G. Collinson, <i>Introduction to Avionics Systems</i>, Springer, 2011.
Reference Books
1. John M. Lloyd, <i>Thermal Imaging System</i>, Plenum Publishing, New York, 1975. 2. Dharendra Patranabis, <i>Telemetry Principles</i>, Tata McGraw Hill, New York, 2000.

Course Code	Course Name	L – T – P	Credits
AE 607	Missile Design	3 – 0 – 0	3

Course Objectives: • To introduce the fundamentals of systems engineering. • To familiarize students with the configuration and functional elements of generic weapon systems and their design requirements. • To provide insight into multidisciplinary missile subsystem design considerations. • To explain the complete missile development cycle.
Unit I: Generic Weapon System Configuration of a Generic Weapon System, Concept of System Engineering and Design, Missile System Generic Functions and Stake holders. Unit II: Missile System Design Requirements Missile Requirement Definition, Key Design Drivers; Missile System Generic Functions, Allocation of System Functions and Requirements to Missile subsystems, Baseline Missile Configuration, Technology Readiness. Unit III: Missile Sub-systems Design Considerations Disciplinary Considerations in Missile Design: Aerodynamics, Structures, Propulsion, Weight, Flight Performance, Addressing Design Uncertainties. Unit IV: Sizing Examples Sizing of Lifting Surface and Control Surface for Stability Management and Maneuverability. Unit V: Missile System Design Case Study 1- Design of an Air Launched Missile. Case Study 2- Design of Generic Hypersonic Vehicle using Optimization Framework.

Unit VI: Missile System Integration into Weapon System Configuration Ground Launched/ Air Launched/ Ship Launched Platform Integration Unit VII: Transformation from Design to Product to Induction into Services Concept of concurrent Design, Development and Production; Milestones Involved: Preliminary Design , Critical Design, Evaluation of Prototype through Ground Testing and Flight Testing , Simulation Based Evaluation, Product V1.0 Readiness and Transfer of Technology to Industry, Certification and Induction
Course Outcomes
After completing this course, the students will be able to: CO1: Apply systems engineering concepts to identify and define the functional elements and stakeholder roles in a generic missile system. CO2: Formulate missile system requirements and allocate them to subsystems, considering key design drivers and technology readiness levels. CO3: Analyze the influence of aerodynamics, propulsion, structural design, and flight performance on overall missile design and address related uncertainties. CO4: Perform sizing of aerodynamic surfaces to ensure stability and maneuverability of missile systems. CO5: Describe the process of missile system development from design to induction, including case studies, system integration, testing, and technology transfer.
Text Books
1. Eugene L. Fleeman, <i>Tactical Missile Design</i>, 2nd Edition, AIAA Education Series, 2012 / 3rd Edition, AIAA Education Series, 2022. 2. David M. Hall, <i>Missile Design and System Engineering</i>, AIAA, 2021.
Reference Books
1. James J. Jerger, <i>System Preliminary Design</i>, D. Van Nostrand Co., Inc., Princeton, New Jersey, 1960. 2. A. Everette Puckett and Simon Ramo, <i>Guided Missile Engineering</i>, McGraw Hill, 1989. 3. Alexander Kossiakoff and William N. Sweet, <i>Systems Engineering Principles and Practice</i>, Wiley, 2011. 4. Robert I. Faulconbridge and Michael J. Ryan, <i>Systems Engineering Practice</i>, Revised Edition, Argos Press, Canberra, 2018.

Course Code	Course Name	L – T – P	Credits
AE 608	Missile Propulsion	3 – 0 – 0	3
Course Objectives: - To provide a comprehensive understanding of propulsion systems used in missiles - To study the working principles and performance of solid, liquid, hybrid, and air-breathing propulsion systems - To introduce design considerations and integration aspects specific to missile applications			
Unit I: Introduction to Missile Propulsion Classification of missiles based on propulsion and mission profile; Missile flight phases and propulsion system requirements; Overview of propulsion system types: solid, liquid, hybrid, air-breathing; Fundamentals of Combustion, Specific impulse, thrust, burn time, staging concepts and Combustion instability.			
Unit II: Solid Propellant Rocket Motors Types of solid propellants: composite, double-base, nitramine-based; Grain configurations and burn rate control; Ignition systems and internal ballistics; Case design, insulation, and nozzle configurations; Thermal protection and structural integrity; Case bonding and insulation techniques.			
Unit III: Liquid Propellant Rocket Engines Mono-propellant and bi-propellant systems; Common fuels and oxidizers (MMH, UDMH, N ₂ O ₄ , LOX, kerosene); Feed systems: pressure-fed vs. pump-fed; Injector design and combustion instability; Cooling methods: regenerative, ablative, radiative; Safety, handling, and storage of propellants.			
Unit IV: Hybrid Rocket Propulsion Fuel and oxidizer combinations; Combustion mechanism and performance; Design challenges and use cases in tactical missiles; Hybrid vs. solid/liquid trade-offs.			
Unit V: Air-Breathing Propulsion for Missiles Ramjets and scramjets: working principles and applications; Thrust generation in supersonic flows; Intake design and combustion control; Air-breathing missile systems (e.g., BrahMos); Combined cycle propulsion (TBCC, RBCC concepts).			
Unit VI: Propulsion System Design and Integration Thrust vector control techniques; Propulsion system sizing and performance estimation; Integration with missile airframe and guidance systems; Environmental and operational constraints; Case studies: Akash, Agni, BrahMos, etc..			
Course Outcomes			
After completing this course, the students will be able to: CO1: Classify different missile propulsion systems and explain their suitability for various mission phases and profiles. CO2: Analyze the working principles and performance characteristics of solid, liquid, and hybrid rocket motors, including grain design and combustion behavior CO3: Describe the design principles and challenges of air-breathing propulsion systems such as ramjets and scramjets used in high-speed missiles.			

CO4: Evaluate propulsion system integration aspects, including sizing, thrust vector control, and coupling with guidance and airframe system
CO5: Apply learned concepts to real-world examples (e.g., Agni, Akash, BrahMos) and assess system-level trade-offs in missile propulsion design.
Text Books
1. George P. Sutton, <i>Rocket Propulsion Elements</i>, 7th Edition, Wiley-Interscience, 2000. 2. Maurice J. Zucrow, <i>Aircraft and Missile Propulsion</i>, Vol. 1 & 2, John Wiley, 1958. 3. Marcel Barrère, <i>Rocket Propulsion</i>, Elsevier Publishing Co., 1960. 4. Maurice J. Zucrow, <i>Gas Dynamics</i>, Volume 1, John Wiley & Sons, 1976. 5. James E. A. John, <i>Gas Dynamics</i>, 3rd Edition, Prentice Hall, 2006. 6. Philip G. Hill and Carl R. Peterson, <i>Mechanics and Thermodynamics of Propulsion</i>, 2nd Edition, Prentice Hall, 1991.
Reference Books
1. Gordon C. Oates, <i>Aerothermodynamics of Gas Turbines and Rocket Propulsion</i>, AIAA Education Series, 1989. 2. William Heiser, David Pratt, Daniel Daley, and Umesh Mehta, <i>Hypersonic Airbreathing Propulsion</i>, AIAA Education Series, 1994.

Course Code	Course Name	L – T – P	Credits
AE 609	Missile Aerodynamics	3 – 0 – 0	3
Course Objectives: • To know the basic concepts of the missile, its shape & configuration • To familiarize with the missile characteristics • To gain the knowledge about SWBLI • To know about the concepts in detail about the airframe effect & integration with engine • To enable students to understand the design methodology of multistage vehicles & stage separation dynamics • To get hands on experiment of wind tunnel testing			
Unit I Introduction to missile airframe, Different missile configurations, bodies of revolution, non-circular shapes, lifting surfaces			
Unit II Low Aspect Ratio characteristics, wing – body – tail interference, prediction of overall characteristics of body dominated configurations and lifting surface dominated configuration, high AOA aerodynamics			
Unit III Shock wave – boundary layer interactions; aerodynamic heating, intake aerodynamics			
Unit IV Engine airframe integration, airframe flexibility effects on aerodynamics. Configuration design methodology of tactical missiles			

Unit V Design methodology of multistage vehicles & Stage separation dynamics
Unit VI Computational & Experimental Methods: CFD & Wind tunnel testing
Course Outcomes
After completing this course, the students will be able to: CO1: To understand the basic concepts of the missile configuration CO2: To gain knowledge about missile characteristics & its aerodynamic properties CO3: To know about SWBLI & basics of intake aerodynamic characteristics CO4: To learn about the missile & airframe integration & the concepts of tactical missiles CO5: To learn about multistage vehicles & its principle CO6: To work on wind tunnel experiments
Text Books
1. Jack N. Nielsen, <i>Missile Aerodynamics</i> , McGraw Hill, 1960. 2. Seng S. Chin, <i>Missile Configuration Design</i> , McGraw-Hill, 1961. 3. Eugene L. Fleeman, <i>Missile Design and Systems Engineering</i> , AIAA Education Series, 2000.
Reference Books
1. John D. Anderson, <i>Hypersonic and High Temperature Gas Dynamics</i> , AIAA, 2000. 2. John D. Anderson, <i>Modern Compressible Flow: With Historical Perspective</i> , 3rd Edition, McGraw Hill, New York, 2004. 3. John D. Anderson, <i>Fundamentals of Aerodynamics</i> , 4th Edition, McGraw Hill, 2006. 4. Edward L. Houghton and Peter W. Carpenter, <i>Aerodynamics for Engineering Students</i> , 5th Edition, Butterworth-Heinemann, Oxford, 2003.

Course Code	Course Name	L – T – P	Credits
AE 610	Missile Guidance & Control	3 – 0 – 0	3
Course Objectives: - To impart knowledge about the missile kinematics and dynamics, transfer function and state space-based modelling of the system and the guidance schemes for the missiles. - To introduce the fundamental concepts of servo systems, instruments, autopilot systems. - To enable the students to understand the classical and modern control methods.			
Unit I Missile Kinematics: Kinematics of various courses, time of flight, lateral acceleration demand and turning rate spectrum for each case.			
Unit II Guidance Laws: Optimal guidance, Advanced PN guidance laws, comparative study of different guidance schemes. Inertial Guidance: Introduction, inertial sensors, coordinate systems and its transformation, Schuler tuning and gimbaled platform systems. Guidance used for ballistic missiles.			
Unit III			

Missile servo system: Hydraulic, Pneumatic and Electromechanical Missile instruments: accelerometer, gyroscopes, altimeter, resolvers Unit IV Missile control methods: Aerodynamic and thrust vector control, Polar and Cartesian control Mathematical modelling: Force and moment equations. Linearization. Transfer function representation of airframe Unit V Autopilot design based on classical approach: Roll stabilization. Lateral autopilots based on various combinations of rate gyro and accelerometer feedbacks. Three loop autopilots. Modern control of missile: State space representation of missile dynamics. Controllability and Observability. State feedback control, Pole placement techniques, Design of observers. Missile autopilot designs based on state space methods.
Course Outcomes After completing this course, the students will be able to: CO1: Learn about the concept of the rigid body kinematics and dynamic equations of motion of the guided Missiles, missile guidance laws, missile servo systems, missile instruments, missile autopilots. CO2: Learn about the linearization of the nonlinear equations of motion, generation of the transfer function and state-space model. CO3: Learn about the concept and design of the different types of autopilots used for the missiles. CO4: Analysis of the autopilots using classical and modern control system tools.
Text Books 1. George M. Siouris, <i>Missile Guidance and Control Systems</i>, Springer-Verlag, New York, 2004. 2. John H. Blakelock, <i>Automatic Control of Aircraft and Missiles</i>, John Wiley, New York, 1991. 3. Paul Zarchan, <i>Tactical and Strategic Missile Guidance</i>, Vol. 199 of <i>Progress in Astronautics and Aeronautics</i>, AIAA, Reston, VA, 2002. 4. Peter Garnell, <i>Guided Weapon Control Systems</i>, 2nd Edition, Pergamon Press, London, 1980. 5. Boris Friedland, <i>Control System Design: An Introduction to State-Space Methods</i>, McGraw-Hill, Singapore, 1987. 1. Katsuhiko Ogata, <i>Modern Control Engineering</i>, Prentice Hall of India, 1995.
Reference Books 1. Rafael Yanushevsky, <i>Modern Missile Guidance</i>, CRC Press, 2007. 2. Nadir A. Shneydor, <i>Missile Guidance and Pursuit: Kinematics, Dynamics and Control</i>, Horwood Publishing Ltd, 1998. 3. Narayan V. Kadam, <i>Practical Design of Flight Control Systems for Launch Vehicles and Missiles</i>, Allied Publishers, 2009. 4. Ching-Fang Lin, <i>Modern Navigation, Guidance and Control Processing</i>, Prentice Hall, 1991.

Course Code	Course Name	L – T – P	Credits
AE 611	Missile Structures	3 – 0 – 0	3
Course Objectives: • To introduce structural requirements and challenges specific to missile systems. • To understand design principles for withstanding aerodynamic, thermal, and inertial loads. • To study material selection and structural configuration for high performance. • To explore integration of subsystems (warhead, propulsion, guidance) within structural layout. • To analyse real-world case studies and design trade-offs in missile structure development.			
Unit I: Introduction to Missile Structures Role and function of structural systems in missiles; Types of missile configurations and structural layouts; Classification of loads: aerodynamic, inertial, thrust, thermal, shock, and vibration; Importance of stiffness, strength, and weight optimization.			
Unit II: Materials for Missile Structures Criteria for material selection: strength-to-weight ratio, temperature resistance, durability; Metals: Aluminum alloys, Titanium, Maraging steels; Composite materials: Carbon and Glass fiber composites; High-temperature materials and coatings; Material behavior under dynamic and thermal loading.			
Unit III: Structural Design Concepts and Analysis Semi-monocoque and monocoque structural concepts; Load paths in slender bodies: axial, bending, torsion; Fin and control surface structural considerations; Analysis methods: static, modal, thermal, dynamic; Structural idealization: panels, frames, ribs, stiffeners.			
Unit IV: Thermal and Dynamic Load Considerations Thermal loads during launch, flight, and re-entry; Thermal protection strategies and ablative materials; Vibration and shock loads during launch; Isolation of sensitive components (seeker, avionics); Structural damping and fatigue.			
Unit V: Integration of Subsystems into Structural Layout Structural interfaces with warhead, propulsion, and guidance sections; Load-bearing partitions and bulkheads; Mounting of electronics and sensors; Payload bay and control system integration; Structural access for maintenance and assembly.			
Unit VI: Design for Manufacturability and Reliability Structural modularity and maintainability; Joints: bolted, riveted, welded, and bonded joints; Tolerances and precision in assembly; Quality assurance, NDT methods; Environmental and field testing for structural validation.			
Unit VII: Case Studies and Emerging Trends Structural design analysis of tactical and strategic missiles; Hypersonic missile structure challenges; Smart structures and embedded sensors; Lightweight structure trends and additive manufacturing; Indigenous missile program structure overview.			

Course Outcomes			
After completing this course, the students will be able to: CO1: Explain the structural layout and functional role of missile structural systems CO2: Evaluate and select suitable materials CO3: Analyze structural behavior and load paths CO4: Integrate subsystems structurally (guidance, propulsion, payload) ensuring proper load transfer, reliability, and maintainability through effective joint design and structural interfaces. CO5: Apply knowledge of modern structural technologies such as smart structures, additive manufacturing, and emerging materials			
Text Books			
1. Elmer F. Bruhn, <i>Analysis and Design of Flight Vehicle Structures</i>, 1973. 2. Michael C. Niu, <i>Airframe Structural Design</i>, Connilit Press, 1988. 3. Eugene L. Fleeman, <i>Tactical Missile Design</i>, 2nd / 3rd Edition, AIAA, 2006 / 2022.			
Reference Books			
1. George M. Siouris, <i>Missile Guidance and Control Systems</i>, Springer, 2004. 2. Timothy H. G. Megson, <i>Aircraft Structures for Engineering Students</i>, Butterworth-Heinemann, 2007. 3. Patrice Bailly, <i>Materials and Structures Under Shock and Impact</i>, Wiley, 2014.			

Course Code	Course Name	L – T – P	Credits
AE 612	UAV/Aircraft Design	3 – 0 – 0	3
Course Objectives: • Understand the terminology and create requirements and evaluate different certification approaches for aircrafts and UAVs. • Analyse and evaluate airworthiness of aircrafts and UAVs. Analyse, evaluate and create Handling qualities and Maneuverability requirements. • Understand Aircraft and UAV design process, project life cycles, stages of aircraft design and create an Aircraft/UAV design process applying these. • Understand and apply initial sizing, aerodynamics, structure and propulsion principles to create an aircraft/UAV • Design using systems engineering approach. • Analyse and create ground and flight-testing procedures for aircrafts and UAVs. • Be able to create design approaches for reliability.			
Unit I Introduction to Systems Engineering; Terminology; Requirements; Certification approaches: aircrafts and UAVs. Airworthiness of aircrafts and UAVs. Airsafety issues. Handling qualities. Maneuverability requirements.			

Unit II Aircraft design; UAV system design. UAV system identification. UAV project life cycles. Stages of Aircraft design. Initial sizing: aircrafts and of UAVs. UAV aerodynamics, structures and propulsion. Ground control systems. Ground and flight testing of UAVs. UAV guidance and Navigation. Design for reliability. Unit III Introduction to UAV system Development.
Course Outcomes After completing this course, the students will be able to: CO1: Understand the terminology, analyse and create requirements and evaluate different certification approaches for aircrafts and UAVs. CO2: Analyse and evaluate airworthiness of aircrafts and UAVs. Analyse, evaluate and create handling qualities and Maneuverability requirements. CO3: Understand Aircraft and UAV design process, project life cycles, stages of aircraft design and be able to create an Aircraft/UAV design process applying these. CO4: Understand and apply initial sizing, aerodynamics, structure and propulsion principles to create an aircraft/UAV. Design using systems engineering approach. CO5: Analyse and create ground and flight-testing procedures for aircrafts and UAVs. Be able to create design approaches for reliability.
Text Books 1. Daniel P. Raymer, <i>Aircraft Design: A Conceptual Approach</i>, AIAA Education Series, 2012. 2. Reg Austin, <i>Unmanned Aircraft Systems</i>, Wiley Publication, 2010. 3. John D. Anderson Jr., <i>Aircraft Performance & Design</i>, McGraw-Hill, 2014. 4. Jay Gundlach, <i>Designing Unmanned Aircraft Systems: A Comprehensive Approach</i>, AIAA Education Series, 2014.
Reference Books 1. Jayaraman Jayaraman, <i>Unmanned Aircraft Systems: A Global View</i>, DRDO, 2014. 2. Eugene L. Fleeman, <i>Missile Design and System Engineering</i>, AIAA Foundation Series, 2014.

	Course Name	L – T – P	Credits
Course Code			
AE 613	UAV Propulsion	3 – 0 – 0	3
Course Objectives: • To introduce the fundamentals of propulsion systems used in UAVs. • To compare various propulsion options suitable for small to medium UAVs. • To understand design, selection, and integration aspects of UAV propulsion. • To provide exposure to electric, piston, and small gas turbine propulsion technologies.			

Unit I: Introduction to UAV Propulsion

Classification of UAVs based on mission and propulsion requirements; Overview of propulsion system options: electric, piston, turbine, hybrid; Power and energy requirements for UAVs; Basic performance parameters: thrust, power-to-weight ratio, efficiency.

Unit II: Electric Propulsion Systems

DC motors, brushless DC (BLDC) motors, ESCs; Propeller matching and thrust calculation; Battery technologies: Li-Po, Li-ion; Power management systems; Design considerations and limitations.

Unit III: Internal Combustion Engines

Two-stroke and four-stroke piston engines; Fuel systems and carburetion; Engine performance metrics; Vibration, cooling, and maintenance considerations; Engine testing and performance evaluation.

Unit IV: Gas Turbine Engines for UAVs

Micro turbojet and turboprop engines; Working principles, components, and cycles; Thrust and efficiency analysis; Starting systems and fuel control; Integration issues in UAV platforms.

Unit V: Hybrid Propulsion and Emerging Technologies

Hybrid-electric propulsion: architecture and benefits; Solar-powered UAV propulsion basics; Fuel cells and alternative fuels; Recent advances in UAV propulsion research.

Unit VI: Design and Integration Considerations

Propulsion system selection criteria based on mission profile; Integration with airframe and payload constraints; Noise and thermal management; Case studies of propulsion systems in real UAVs.

Course Outcomes

After completing this course, the students will be able to:

CO1: Classify UAV propulsion systems and analyze power and energy requirements based on mission profiles and UAV types.

CO2: Evaluate and design electric propulsion systems using BLDC motors, propellers, and batteries for various UAV applications.

CO3: Assess performance and operational characteristics of internal combustion engines and identify their integration requirements in UAV platforms.

CO4: Explain the principles and components of micro gas turbine engines and analyze their suitability for UAV propulsion.

CO5: Compare hybrid and emerging propulsion technologies, and justify propulsion system selection and integration strategies for specific UAV missions.

Text Books

1. Jack D. Mattingly, *Elements of Propulsion: Gas Turbines and Rockets*, 1st Edition, AIAA, 2006.
2. Daniel P. Raymer, *Aircraft Design: A Conceptual Approach*, 5th Edition, AIAA Education Series, 2012.
3. Jay Gundlach, *Designing Unmanned Aircraft Systems: A Comprehensive Approach*, AIAA Education Series, 2014.

4. Reg Austin, *Unmanned Aircraft Systems: UAVS Design, Development and Deployment*, Wiley, 2010.
5. Jayaraman Jayaraman, *Unmanned Aircraft Systems: A Global View*, DRDO, 2014.
6. John D. Anderson, *Aircraft Performance and Design*, McGraw-Hill, 2014.

Reference Books

1. Maurice J. Zucrow, *Aircraft and Missile Propulsion*, Vol. 1 & 2, John Wiley, 1958.
2. George P. Sutton and Oscar Biblarz, *Rocket Propulsion Elements*, 8th Edition, Wiley-Interscience, 2010.
3. Jacob Fraden, *Handbook of Modern Sensors*, 4th Edition, Springer, 2016.
4. Thomas M. Flynn, *Electric Propulsion for Small UAVs*, AIAA Technical Papers,
5. Various Manufacturers, *UAV Propulsion System Manufacturer Datasheets*,

Course Code	Course Name	L – T – P	Credits
AE 614	UAV Aerodynamics	3 – 0 – 0	3

Course Objectives:

- To understand aerodynamic principles as applied to small and medium UAVs.
- To analyze the impact of size, Reynolds number, and operating conditions on UAV aerodynamics.
- To introduce students to fixed-wing, rotary-wing, and hybrid UAV configurations.
- To cover low Reynolds number effects, flow control, and design trade-offs specific to UAVs.

Unit I: Introduction to UAVs and Configurations

Classification of UAVs (Fixed-wing, Rotary-wing, Flapping-wing, Hybrid); Typical mission profiles and aerodynamic implications; Introduction to design considerations: endurance, agility, payload.

Unit II: Low Reynolds Number Aerodynamics

Reynolds number effects on airfoil performance; Laminar separation bubbles and transition; Airfoil selection for UAVs; Wind tunnel and CFD techniques for low Re studies.

Unit III: Fixed-Wing UAV Aerodynamics

Wing planform design and optimization; Lift, drag, and moment estimation; Effects of wing sweep, taper, and dihedral; Control surface aerodynamics.

Unit IV: Rotary-Wing and VTOL UAV Aerodynamics

Fundamentals of rotor aerodynamics; Momentum theory and blade element theory; Hover and forward flight analysis; Vortex ring state and autorotation; Aerodynamics of tilt-rotor and VTOL systems.

Unit V: Case Studies and Advanced Topics

Aerodynamic analysis of popular UAV designs.; MAVs and bio-inspired flight.; AI/ML for aerodynamic prediction.

Course Outcomes	
After completing this course, the students will be able to: CO1: Classify and analyze different UAV configurations. CO2: Explain low Reynolds number aerodynamic phenomena. CO3: Estimate aerodynamic forces and moments for fixed-wing and rotary-wing UAVs. CO4: Utilize aerodynamic design and validation tools such as CFD and wind tunnel testing, to assess and improve UAV performance. CO5: Applying AI/ML for aerodynamic prediction.	
Text Books	
1. Thomas J. Mueller (Ed.), <i>Fixed and Flapping Wing Aerodynamics for Micro Air Vehicle Applications</i>, AIAA, 2001. 2. Simon Newman, <i>Model Aircraft Aerodynamics</i>, The Crowood Press, 2000. 3. J. Gordon Leishman, <i>Principles of Helicopter Aerodynamics</i>, Cambridge University Press, 2000.	
Reference Books	
1. John D. Anderson, <i>Fundamentals of Aerodynamics</i>, McGraw-Hill, 2016. 2. Edward L. Houghton and Peter W. Carpenter, <i>Aerodynamics for Engineering Students</i>, 5th Edition, Butterworth-Heinemann, Oxford, 2003. 3. John D. Anderson, <i>Introduction to Flight</i>, 5th Edition, McGraw Hill, 2005.	

Course Code	Course Name	L – T – P	Credits
AE 615	UAV Guidance & Control	3 – 0 – 0	3
Course Objectives: • To impart knowledge about the UAVs’ kinematics and dynamics, transfer function and state space-based modelling of the system and the guidance schemes. • To introduce the fundamental concepts of servo systems, instruments, autopilot systems. • To enable the students to understand the classical and modern control methods.			
Unit I UAV Guidance: Overview of UAV guidance techniques, General guidance laws for UAVs, Kinematic models for guidance, Path planning, Way-point guidance, Path following for straight line and orbits, Guidance of swam of UAVs, obstacle avoidance guidance. Vision Based Navigation and Target Tracking for Unmanned Aerial Vehicles			

Inertial guidance: Introduction, inertial sensors, coordinate systems and its transformation, Schuler tuning and related issues. INS systems, GPS-INS Integration, Data fusion. Servo systems: Electromechanical Unit II UAV Mathematical Modeling: Equations of Motion for an Unmanned Aerial Vehicle, Coordinate Systems, Small Perturbation Theory, linearization and transfer function representation. Stability Analysis for Unmanned Aerial Vehicles. Unit III UAV Control: Classical Controller Design for Unmanned Aerial Vehicles, Lateral-directional and longitudinal autopilot design using success loop closure. Modern control of UAVs: State space representation of UAV dynamics. Controllability and Observability. Design of UAV autopilots based on State feedback, Design of observers. Advanced modern techniques for UAV autopilot design.
Course Outcomes After completing this course, the students will be able to: CO1: Learn about the concept of the rigid body kinematics and dynamic equations of motion of UAVs, guidance laws, servo systems, instruments, and autopilots. CO2: Learn about the linearization of the nonlinear equations of motion, generation of the transfer function and state-space model. CO3: Learn about the concept and design of the different types of autopilots used for the UAVs. CO4: Analysis of the autopilots using classical and modern control system tools.
Text Books 1. Jay Gundlach, <i>Designing Unmanned Aircraft Systems: A Comprehensive Approach</i>, AIAA Education Series, AIAA, 2012. 2. Rafael Yanushevsky, <i>Guidance of Unmanned Aerial Vehicles</i>, CRC Press, 2011. 3. John H. Blakelock, <i>Automatic Control of Aircraft and Missiles</i>, John Wiley, New York, 1991. 4. Boris Friedland, <i>Control System Design: An Introduction to State-Space Methods</i>, McGraw-Hill, Singapore, 1987. 1. Randal W. Beard and Timothy W. McLain, <i>Small Unmanned Aircraft: Theory & Practice</i>, Princeton University Press, 2012.
Reference Books 1. Amitava Bose, Somnath Puri, Paritosh Banerjee, <i>Modern Inertial Sensors and Systems</i>, Prentice-Hall of India, 2008. 2. Ian Moir, Allan Seabridge, Malcolm Jukes, <i>Military Avionics Systems</i>, Wiley, 2006.

Course Code	Course Name	L – T – P	Credits
AE 616	UAV Structures	3 – 0 – 0	3
Course Objectives: - To introduce structural concepts specific to Unmanned Aerial Vehicles (UAVs). - To understand the unique structural design challenges of small and lightweight aerial systems. - To study structural loads, material selection, stress analysis, and failure modes for UAVs. - To expose students to composite materials, flexible/morphing structures, and rapid prototyping techniques used in UAV construction.			
Unit I: Introduction to UAV Structures Overview of UAV types and structural configurations; Unique challenges: weight constraints, payload integration, miniaturization; Design philosophy for UAV structural systems.			
Unit II: Structural Load Estimation Identification of aerodynamic, inertial, and ground loads on UAVs; Load paths in fixed-wing and rotary-wing UAVs; Flight envelope and load factor considerations; Structural sizing and preliminary load calculations.			
Unit III: Materials for UAV Structures Selection criteria: strength-to-weight ratio, manufacturability, cost; Composite materials: carbon fiber, glass fiber, aramid fibers; Foam, balsa wood, plastics, and 3D printed materials for MAVs; Hybrid material structures and recent innovations.			
Unit IV: Structural Components and Subsystems Wing spars, ribs, skin, and joinery techniques; Fuselage structures: monocoque, semi-monocoque, truss-type; Tail boom and rotor hub structures (for rotary UAVs); Payload integration and mounting structures.			
Unit V: Structural Analysis Techniques Stress and deformation analysis in UAV airframes; Beam, shell, and plate theory applications; Finite Element Modeling (FEM) for UAVs; Fatigue and failure analysis under cyclic loads.			
Unit VI: Manufacturing and Assembly Techniques Composite layup and curing methods; Additive manufacturing and rapid prototyping for UAV components; Adhesives, bolted joints, and mechanical fasteners; Quality control and structural testing methods.			
Unit VII: Advanced Topics in UAV Structures Morphing and flexible wing structures Aeroelasticity in lightweight UAVs; Damage tolerance and repair techniques for field-deployed UAVs; Embedded sensors for structural health monitoring			

Course Outcomes
After completing this course, the students will be able to: CO1: Identify and describe structural configurations and design challenges unique to various UAV types CO2: Estimate aerodynamic and inertial loads on UAV structural components and perform preliminary structural sizing based on flight envelope and mission profiles. CO3: Select appropriate materials for UAV structural applications based on performance, manufacturability, and cost, including the use of composites and hybrid materials. CO4: Analyze and design key UAV structural components. CO5: Evaluate manufacturing, assembly, and health monitoring techniques suitable for UAV structures, including composite fabrication, additive manufacturing, and embedded sensor systems.
Text Books
1. Megson, T.H.G., <i>Aircraft Structures for Engineering Students</i>, Elsevier, 2021 2. Niu, M.C., <i>Airframe Structural Design</i>, Conmilit Press, 1988
Reference Books
1. Daniel, Isaac M. and Omer Ishai, <i>Engineering Mechanics of Composite Materials</i>, 2nd Edition, Oxford University Press, 2006. 2. Pei, Shengwei, <i>UAV Design: From Structure to Flight</i>, Springer, 2023.

Course Code	Course Name	L – T – P	Credits
AE 617	Nonlinear and Robust Control	3 – 0 – 0	3
Course Objectives: • To impart the knowledge about the linear and nonlinear systems, stability analysis, and their control. • To introduce the fundamental concepts of linearization, uncertainty, disturbance, delay, and observer. • To enable the students to understand the control approaches for nonlinear systems and its applications in autopilot design.			
Unit I Introduction to Nonlinear Systems, Stability analysis.			
Unit II Feedback linearization, Input-State and Input Output Linearization, Robust Feedback Linearization. Sliding Mode Control and Sliding Mode Observers.			
Unit III Uncertainties, variation and unmodelled lags, Robust control based on Uncertainty and Disturbance Estimation. Time Delay Control, Inertial Delay Control. Disturbance Observer. State and Disturbance Observers. Applications in missile and aircraft autopilot design.			

Course Outcomes	
After completing this course, the students will be able to: CO1: Learn about the concept of nonlinear system, equilibrium point, stability, state trajectory, linearization, uncertainty, disturbance, delay, and observer. CO2: Learn the various types of control approaches to handle the nonlinear systems. CO3: Learn about the design of a nonlinear control system and its application in Missile and UAV autopilot.	
Text Books	
1. Jean-Jacques E. Slotine and Weiping Li, <i>Applied Nonlinear Control</i>, Prentice-Hall, NJ, 1991. 2. Hassan K. Khalil, <i>Nonlinear Systems</i>, 3rd Edition, Prentice Hall, 2002. 3. Hassan K. Khalil, <i>Nonlinear Control</i>, Pearson Education, 2015. 4. Shankar Sastry, <i>Nonlinear Systems: Analysis, Stability, and Control</i>, Springer-Verlag New York Inc., 1999.	
1. Fan Lin, <i>Robust Control Design: An Optimal Control Approach</i>, Wiley, 2007.	
Reference Books	
1. John H. Blakelock, <i>Automatic Control of Aircraft and Missiles</i>, Wiley, 1991. 2. Peter Garnell, <i>Guided Weapon Control Systems</i>, Pergamon Press, London, 1980. 3. Asif Sabanovic, Levant Fridman, and Sarah Spurgeon, <i>Variable Structure Systems: From Principles to Implementation</i>, IEE Control Series No. 66, 2004. 4. Richard C. Dorf and Robert H. Bishop, <i>Modern Control Systems</i>, Addison Wesley, 1998. 5. Graham C. Goodwin, Stefan F. Graebe, and Mario E. Salgado, <i>Control System Design</i>, Prentice Hall India, 2002. 6. Hassan K. Khalil, <i>High-Gain Observers in Nonlinear Feedback Control</i>, SIAM, 2017. 7. Jun Yang, Shihua Li, Wen-Hua Chen, and Xisong Chen, <i>Disturbance Observer-Based Control: Methods and Applications</i>, CRC Press, 2014.	

Course Code	Course Name	L – T – P	Credits
AE 618	Avionics	3 – 0 – 0	3
Course Objectives: • To impart the knowledge about the various types of Navigation used by air vehicles. • To introduce the fundamental concepts of navigation and its variants: radio navigation, doppler navigation, GPS based navigation, navigational aids during Landing. • To enable the students to understand cockpit displays, Data bus, FMS, and Redundant systems.			
Unit I Maps and geodesy; co-ordinate systems and transformations; great circle and rhumb line navigation; dead reckoning;			

Unit II INS-gyroscopes and accelerometers, platform stability and strapped down INS; horizontal and vertical mechanizations in INS; altimeter, airspeed indicator, compass and gyro compass;
Unit III Radio navigation - beacons, VOR, DME, LORAN and other nav-aids; primary and secondary surveillance radars; Doppler navigation;
Unit IV GPS principles - space and control segments architecture; DOP and computation of position and velocity; GPS in air, surface and space navigation; considerations in air traffic control. Aids to approach and landing, Data fusion.
Unit V Head-Up displays: Helmet mounted displays; Head down displays. Displays Technology. Control and data entry. FMS. Avionics system integration. Data bus. Introduction to safety systems.
Course Outcomes
After completing this course, the students will be able to: CO1: Learn the various types of the navigation methods commonly used for the air vehicles. CO2: Learn the various types of the instruments: airspeed indicator, windvanes, altimeter, machmeter, turn coordinator, compass. CO3: Learn about the concept of INS, GPS, Radar, Displays, data entry, Data bus, FMS, FCS.
Text Books
1. Merrill I. Skolnik, <i>Introduction to Radar Systems</i>, Tata McGraw Hill, New Delhi, 2001. 2. Myron Kayton and Walter R. Fried, <i>Avionics Navigation Systems</i>, John Wiley & Sons, 1997. 3. Albert Helfrick, <i>Principles of Avionics</i>, Avionics Communications, 2009.
Reference Books
1. John H. Blakelock, <i>Automatic Control of Aircraft and Missiles</i>, Wiley, 1991. 2. Anthony Lawrence, <i>Modern Inertial Technology</i>, Springer, 1998. 3. Ching Fang Lin, <i>Modern Navigation, Guidance and Control Processing</i>, Prentice Hall, 1991. 4. Ian Moir, Allan Seabridge, and Malcolm Jukes, <i>Military Avionics Systems</i>, Wiley, 2006. 5. Amitava Bose, Somnath Puri, and Paritosh Banerjee, <i>Modern Inertial Sensors and Systems</i>, Prentice Hall of India, 2008.

Course Code	Course Name	L – T – P	Credits
AE 619	Structural Dynamics and Aeroelasticity	3 – 0 – 0	3
Course Objectives: - To impart knowledge about Structural Dynamics and Aeroelasticity. - To introduce the fundamental of Aeroelasticity and Fluid Structure Interaction. - To enable the students to understand the concepts of Structural Stability, Divergence and Flutter			
Unit I : Single, Double and Multi-Degree-of-Freedom Systems Review of SDOF systems, Free/forced and damped/undamped vibrations, Determination of modal parameters (natural frequencies, mode shapes, and damping), Orthogonality of modes, Steady state and transient response using modal analysis.			
Unit II: Continuous systems Vibration of strings, bars, and beams (Euler and Timoshenko beam theories); Various boundary conditions; Determination of natural frequencies and modes; Modeling of damping, Rayleigh method, Steady state and transient response using modal analysis, Approximate methods for computing natural frequencies and modes.			
Unit III :Aeroelasticity Static and dynamic aeroelasticity, Discrete models for aeroelastic problems, Steady state aeroelastic phenomenon with specific reference to wing divergence and control system reversal. Flutter analysis and prediction.			
Course Outcomes			
After completing this course, the students will be able to: CO1: Learn about Aeroelasticity CO2: Learn design of Aeroelastic Models CO3: Solve problems on Vibration and Aeroelasticity			
Text Books			
1. Dewey H. Hodges and Grant Alvin Pierce, <i>Introduction to Structural Dynamics and Aeroelasticity</i> , Cambridge University Press, 2002.			
Reference Books			
1. Raymond L. Bisplinghoff, Holt Ashley & Robert L. Halfman, <i>Aeroelasticity</i> , Courier Dover Publications, 1996			

Course Code	Course Name	L – T – P	Credits
AE 620	Experimental Methods in Fluid Mechanics	3 – 0 – 0	3
Course Objectives: - To understand the importance of basics of fluid mechanics & its experiments - To familiarize with different instruments used for pressure, temperature, force & moment, shear stress, mass & volume flow measurements & their usage. - To gain knowledge on water tunnels and wind tunnels & their principles used for the measurements. - To know in detail about the flow visualization, data acquisition & processing techniques.			
Unit I: Introduction Review of concepts of Fluid Mechanics, Introduction to experimental methods, Basic concept of dynamic measurements.			
Unit II: Pressure Measurements Manometers, Barometers, Pressure transducers, Pitot probe, Pitot-static probe, High- and low-pressure Gauges, Dynamic pressure gauges, Pressure sensitive paints, Sound measurement.			
Unit III: Velocity Measurements Velocity and Mach number from pressure measurements, Laser Doppler Anemometer (LDA), Hot-Wire Anemometer (HWA), Particle Image Velocimetry (PIV), Particle Tracking Velocimetry (PTV).			
Unit IV: Temperature Measurements Thermometers, Thermocouples, Pyrometers/optical methods.			
Unit V: Force and Moment Measurements Strain gauges, Piezoelectric transducers, Accelerometers, Force/torque sensors, External and Internal wind tunnel balances.			
Unit VI: Shear stress measurements Floating element method, momentum integral method, Preston tube, Fence Technique, Heat Transfer Gauge.			
Unit VII: Mass and Volume Flow measurements Direct and Indirect methods, Rotameters, Drag-Body meters, Ultrasonic flow meters, Vortex-Shedding flow meters, Direct mass flow meters.			
Unit VIII : Flow visualization Wool tufts, dyes, smoke wire, smoke rake, smoke tunnel, shadow graph, Schlieren, particles, bubbles, Fluorescence.			
Unit IX: Measurements in Turbo machineries, Wind Tunnel Testing; Water Tunnels Testing, Data Acquisition and Processing; Uncertainty Analysis.			
Course Outcomes			

After completing this course, the students will be able to: CO1: To understand the importance of basic fluid mechanics & its experiments CO2: Use different instruments for measuring pressure, velocity, temperature, force & moment etc. CO3: To understand the usage of different tunnels (wind & water) used in measurements. CO4: To gain the knowledge of flow visualization technique and data acquisition & processing methods
Text Books
1. E Rathakrishnan, <i>Instrumentation, Measurements and Experiments in Fluids</i>, 2nd Edition, CRC Press, 2012. 2. Cameron Tropea, Alexander L. Yarin, John F. Foss (Eds), <i>Handbook of Experimental Fluid Mechanics</i>, Springer, 2007.
Reference Books
1. Robert A. Granger, <i>Experiments in Fluid Mechanics</i>, Holt, Rinehart and Winston, Inc., 1988. 2. Markus Raffel, Christian E. Willert, Fulvio Scarano, Christian Kähler, Steven T. Wereley, Jürgen Kompenhans, <i>Particle Image Velocimetry</i>, 3rd Edition, Springer, 2018.

Course Code	Course Name	L – T – P	Credits
AE 621	Experimental Aerodynamics	3 – 0 – 0	3
Course Objectives: • To provide an in-depth understanding of wind tunnel types and their operational principles across various flow regimes (subsonic to hypersonic). To familiarize with different wind tunnels. • To develop knowledge of fundamental measurement techniques for pressure, velocity, temperature, and aerodynamic forces. • To familiarize students with modern flow visualization methods used in aerodynamic testing and diagnostics. • To introduce data acquisition systems and error analysis techniques, essential for experimental reliability and accuracy. • To enable students to plan and interpret aerodynamic experiments, combining theoretical knowledge with practical instrumentation. • To have hands on experience on wind tunnel testing.			
Unit I: Wind Tunnels Classification of wind tunnels, Subsonic wind tunnel, Transonic wind tunnel, Supersonic wind tunnel, Hypersonic wind tunnel, Special purpose wind tunnels: Icing tunnel, plasma tunnel, atmospheric tunnel, automobile wind tunnel etc., Wind Tunnel Calibration.			
Unit II: Pressure Measurements Manometers, Pressure Probes, Pressure transducers, Pressure sensitive paints.			
Unit III: Velocity measurements Pressure-based velocity measurements, Hot-wire anemometers (CTA & CCA), Laser Doppler anemometer (LDA), Particle Image Velocimetry (PIV).			

Unit IV: Temperature Measurements Thermocouples, RTD, Temperature sensitive paints, Pyrometers. Unit V: Measurement of aerodynamic forces and moments Wind Tunnel Balances, Measurement of wall shear stress. Unit VI: Flow Visualization Surface flow visualization, Tufts, Particle tracer methods: Smoke or Die injection method, Smoke wire, Helium or Hydrogen bubble technique, Optical methods: Shadowgraph, Schlieren photography and Interferometry. Unit VII: Data acquisition, Data processing, Uncertainty analysis.
Course Outcomes After completing this course, the students will be able to: CO1: To understand the importance of experimental study in aerodynamics. Design the experiments. To understand different type of wind tunnels. Also, should be able to operate Subsonic Wind Tunnel and Hypersonic Table Top Shock Tunnel. Calibrate these wind tunnels. CO2: Use different pressure probes (Pitot-static probe, Pitot probe, 3-Hole probe, 5-Hole probe), Micromanometers. CO3: Use various devices to measure the velocity such as Hot-wire Anemometer (HWA) and Particle Image Velocimetry (PIV) etc CO4: Understand and measure the temperature change using different techniques CO5: Understand and Measure aerodynamic forces & moments using wind tunnel balances. CO6: Understand the different flow visualization techniques. Conduct visualization experiments over different models in Subsonic Wind Tunnel and Hypersonic Table Top Shock Tunnel.
Text Books 1. E Rathakrishnan, <i>Instrumentation, Measurements and Experiments in Fluids</i>, 2nd Edition, CRC Press, 2012.
Reference Books 1. Alan Pope and John J. Harper, <i>Low-Speed Wind Tunnel Testing</i>, 1st Edition, John Wiley & Sons, 1966. 2. Alan Pope and Kenneth L. Goin, <i>High-Speed Wind Tunnel Testing</i>, 1st Edition, John Wiley & Sons, 1965. 3. Bernhard H. Goethert, <i>Transonic Wind Tunnel Testing</i>, 1st Edition, Pergamon Press, 1961. 4. Ernest O. Doebelin, <i>Measurement Systems: Application and Design</i>, 5th Edition, McGraw-Hill, 2003. 5. Cameron Tropea, Alexander L. Yarin, John F. Foss (Eds), <i>Handbook of Experimental Fluid Mechanics</i>, 1st Edition, Springer, 2007.

Course Code	Course Name	L – T – P	Credits
AE 622	Computational Aerodynamics		3
Course Objectives: - To introduce the fundamentals of computational approaches in aerodynamics. - To familiarize students with numerical techniques for solving fluid flow equations. - To enable students to analyze inviscid and viscous aerodynamic flows computationally. - To develop proficiency in using CFD tools and interpreting simulation results. ☐ To equip students to handle real-world aerodynamic problems using CFD techniques.			
Unit I : Introduction to Computational Aerodynamics Historical development of CFD in aerodynamics, Governing equations, model equations and classification of PDEs. Euler equations, Navier Stokes equations, Burger's equation.			
Unit II: Discretization Techniques Grid generation: structured and unstructured meshes; Finite Difference Method (FDM): forward, backward, and central difference schemes; Finite Volume Method (FVM): integral approach, control volume concept; Finite Element Method (FEM): basics and applications in aerodynamics; Stability, consistency, convergence, and accuracy.			
Unit III: Numerical Domain Analysis of numerical schemes for accuracy, stability, dispersion and dissipation. RK method, schemes with spectral-like resolution, Riemann solver, TVD, and ENO. Implementation of boundary conditions.			
Unit IV: Inviscid Flows Solution of Laplace equation for potential flow; Panel methods for 2D and 3D bodies; Vortex lattice methods; Euler equations: shock capturing and shock fitting methods; Numerical fluxes: Roe, Van Leer, and AUSM schemes.			
Unit IV: Viscous Flows and Turbulence Modeling Navier-Stokes equations for laminar and turbulent flows; Turbulence models: zero-equation, $k-\epsilon$, $k-\omega$, and RANS; Boundary layer equations and wall functions; Grid resolution and y^+ criterion; Introduction to LES and DNS (conceptual level).			
Unit V: Applications and Practical CFD Grid convergence and validation of results; CFD software introduction and lab sessions; Flow over airfoils, wings, and bluff bodies; High-speed flow simulations and compressibility effects; Case studies: drag estimation, lift prediction, shock-boundary layer interaction, shock-capturing, aeroacoustics and aeroelastic computations.			
Course Outcomes			
CO1. Understand and formulate the governing equations of aerodynamic flows for different flow regimes. CO2. Apply appropriate numerical techniques for discretization and solution of aerodynamic flow equations. CO3. Analyze and simulate inviscid and viscous flow fields around aerodynamic bodies			

using CFD tools.
CO4. Evaluate the performance of turbulence models and understand their limitations in various flow conditions.
CO5. Design and interpret CFD-based aerodynamic analyses for real-world aerospace configurations.
Text Books
1. Josef Blazek, <i>Computational Fluid Dynamics: Principles and Applications</i>, 2nd Edition, Elsevier, 2006. 2. John D. Anderson, <i>Computational Fluid Dynamics: The Basics with Applications</i>, 1st Edition, McGraw-Hill, 1995.
Reference Books
1. Charles Hirsch, <i>Numerical Computation of Internal and External Flows</i>, Volumes 1 & 2, Butterworth-Heinemann, 2007. 2. Joe F. Thompson, Bharat K. Soni, Nigel P. Weatherill, <i>Handbook of Grid Generation</i>, CRC Press, Taylor & Francis, 1998. 3. Eleuterio F. Toro, <i>Riemann Solvers and Numerical Methods for Fluid Dynamics</i>, 3rd Edition, Springer, 2009. 4. Stephen B. Pope, <i>Turbulent Flows</i>, Cambridge University Press, 2000.

Course Code	Course Name	L – T – P	Credits
AE 623	Hypersonic Aerodynamics	3 – 0 – 0	3
Course Objectives: • To introduce students to the fundamental physics governing hypersonic aerodynamics. • To analyze shock wave behavior and high-temperature gas effects in hypersonic regimes. • To understand viscous-inviscid interaction and its implications for vehicle design. • To provide insight into aerodynamic heating and real gas effects in vehicle design. • To expose students to modern computational and experimental tools used in hypersonic studies.			
Unit I: Introduction to Hypersonic Flow Physics Definition and characteristics of hypersonic flow; Differences between hypersonic and supersonic aerodynamics; Shock layer and entropy layer formation; Hypersonic similarity parameters.			
Unit II: Shock Waves and Expansion Processes Normal, oblique, and bow shocks; Shock detachment and standoff distance; Prandtl-Meyer expansions; Shock-shock and shock-boundary layer interactions.			
Unit III: Hypersonic Boundary Layers and Viscous Effects Laminar and turbulent hypersonic boundary layers; Viscous-inviscid interaction (strong and weak); Aerodynamic heating and surface temperature effects; Thermal protection systems overview.			
Unit IV: High-Temperature Effects and Real Gas Behavior			

Thermodynamics of high-temperature gases; Dissociation, ionization, and vibrational excitation; Calorically perfect vs. thermally perfect vs. real gas; Equilibrium and nonequilibrium chemistry. Unit V: Aerodynamics of Hypersonic Configurations Blunt vs. sharp nose aerodynamics; Lift and drag at hypersonic speeds; Shock expansion theory and Newtonian theory; Stability and control surface issues in hypersonic vehicles. Unit VI: Hypersonic Vehicle Design Considerations Design of hypersonic cruise vehicles and reentry vehicles; Trade-offs: heating, drag, lift-to-drag ratio; Wave drag and aerodynamic efficiency; Material and structural integration. Unit VII: Computational and Experimental Techniques Wind tunnels for hypersonic testing (shock tunnel, expansion tube, arc jet); Flow diagnostics and instrumentation; CFD modeling challenges in hypersonic aerodynamics; Validation and verification of computational results.
Course Outcomes After completing this course, the students will be able to: After completing this course, the students will be able to: CO1: Explain the unique features and governing principles of hypersonic aerodynamic flows. CO2: Analyze complex shock structures and viscous interactions in high-speed flows. CO3: Evaluate the influence of real gas effects and thermal non-equilibrium in aerodynamic analysis. CO4: Apply hypersonic flow theory to aerodynamic design of vehicles and estimate thermal loads. CO5: Utilize computational and experimental approaches to investigate hypersonic aerodynamic problems.
Text Books 1. John D. Anderson Jr., <i>Hypersonic and High Temperature Gas Dynamics</i>, 2nd Edition, AIAA Education Series, 2006. 2. John J. Bertin, <i>Hypersonic Aerothermodynamics</i>, AIAA Education Series, 1994. 3. John D. Anderson Jr., <i>Modern Compressible Flow: With Historical Perspective</i>, 3rd Edition, McGraw-Hill, 2004. 4. Maurice Rasmussen, <i>Introduction to Hypersonic Flow</i>, Krieger Publishing, 1994.
Reference Books 1. John J. Bertin and Russell M. Cummings, <i>Aerodynamics for Engineers</i>, 6th Edition, Prentice Hall, 2013. 2. Ernst Heinrich Hirschel, <i>Basics of Aerothermodynamics</i>, 2nd Edition, Springer, 2015. 3. Roderick N. Cox and Leonard F. Crabtree, <i>Elements of Hypersonic Aerodynamics</i>, Academic Press, 1965. 4. Wallace D. Hayes and Ronald F. Probstein, <i>Hypersonic Flow Theory</i>, Academic Press Company, 1959. 5. Wallace D. Hayes and Ronald F. Probstein, <i>Hypersonic Inviscid Flow</i>, Dover Publications, 2004.

Course Code	Course Name	L – T – P	Credits
AE 624	Aircraft Assembly, Inspection & Tests	3 – 0 – 0	3
Course Objectives: - To impart knowledge about Aerospace Manufacturing and Assembly. - To introduce the fundamental concepts of Engineering drawing, Fits and Tolerances - To enable students to understand various materials & resources used in aircraft assembly - To gain knowledge about various inspection and Tests in aircraft assembly			
Unit I Aerospace manufacturing: A Systems approach and standards, Incoming inspection, documentation, record keeping, identification & traceability, Assembly workplace.			
Unit II Engineering drawing awareness: Basic knowledge of Engg. Drawing: Components & assemblies Electric, Fuel, Lubrication, Hydraulic, Pneumatic systems and symbols used.			
Unit III Materials & resources for assembly: Brief on Aerospace materials & consumables. Jigs and fixtures, Calibration, Jig less assembly, Manual vrs automated assembly, Case studies			
Unit IV Sub-assembly & Final assembly: Type of fits, Tolerancing, Basics of joining--Welding, Brazing, Soldering & Riveting, Modern joining methods. Set making, Static & Dynamic Balancing, Transmission assembly, Assembly and failures, Modular constructions, Interchangeability, Selective assembly. Digital/Virtual technologies in assembly, Augmented reality. Pipe lines operations, Clamping/ cleating of pipelines, Electrical cables and conduits, Continuity, insulation, and bonding, Functional Tests, Certification, Case studies. Statistical Process controls/ Process capability, Surface treatments and corrosion prevention.			
Unit IV Inspection & Tests : Non Destructive Testing(NDT), Static and Dynamic tests on aircraft, Ground Vibration Tests(GVT)			
Course Outcomes			
After completing this course, the students will be able to: CO1: Learn various aircraft standards & practices followed in the assembling of the aircraft CO2: Learn to understand the engineering drawings used in assembly, its concepts & systems CO3: Learn about the various materials & resources used in assembly CO4: Learn various inspection techniques & to know about the assembly procedures.			
Text Books			
1. Douglas F. Horne, <i>Aircraft Production Technology</i> , Cambridge University Press, 1986. 2. Tao Li, <i>Aircraft Assembly Process Design for Complex Systems Installation and Test Integration</i> , Cranfield University, 2019. 1. Ronald Sterkenburg, <i>Aircraft Maintenance & Repair</i> , 8th Edition, McGraw-Hill, New York, 2019.			

Reference Books	
1. Robert Wicks, <i>Airbus A380 Owner's Workshop Manual, 2005 to Present</i> , 1st Edition, Haynes Publishing, 2017. 2. Pradip K. Saha, <i>Aerospace Manufacturing Processes</i> , 1st Edition, CRC Press, 2016. 3. Federal Aviation Administration, <i>AMT Handbook General</i> , FAA-H-8083-30A, 2018.	

Course Code	Course Name	L – T – P	Credits
AE 641	Aerospace Engineering Lab.	0 – 0 – 4	2

Course Objectives:

- To provide hands-on experience with core aerodynamic measurements techniques in wind tunnel environments.
- To introduce students to fundamental control engineering concepts through experiments.
- To impart experimental knowledge in material and structural testing
- To develop skills in aeromodelling

1. Aerodynamics

- Experiments in Subsonic Wind Tunnel
- Experiments in Table Top Hypersonic Wind Tunnel
- Experiments in Supersonic Jet Facility
- Flow Visualization Experiments

2. Control Engineering

- Pitch and Roll position Control of the 3D Hover System
- Q-Drone Hover Test
- Position and speed control of LSIP
- Balance and Swing Control of LSIP

3. Structural Analysis

- Testing Mechanical Properties of Materials using UTM
- Vibration Test
- Surface Roughness Test
- Composite material manufacturing and testing
- Surface coatings

4. Aeromodelling

- Fixed Wing UAVs
- Drones
- Flight Simulator training

Course Outcomes
After completing this course, the students will be able to: CO1: Perform and interpret fundamental aerodynamic tests, including pressure, velocity, and force measurements, and visualize flow features in experimental setups. CO2: Demonstrate an understanding of feedback control principles and dynamic behavior through real-time control of physical systems like inverted pendulums and hover platforms. CO3: Conduct mechanical and structural property testing using UTM and vibration analysis, and interpret material behavior including composites under varied loading conditions. CO4: Design and fabricate basic UAV and drone models, gaining proficiency in system integration and control through physical construction and simulator-based flight training.
References: Laboratory Manual

Master of Technology in Automation and Robotics

Brief Description: M. Tech in Automation and Robotics is a multidisciplinary postgraduate program offered by the School of Robotics, Defence Institute of Advanced Technology (DIAT). The program is open to graduates from diverse engineering backgrounds, including Mechanical Engineering, Electrical/Electronics/Telecommunication Engineering/Computer Science/Information Technology/Industrial Engineering, and Instrumentation Engineering.

This program is structured to equip students with in-depth knowledge, cutting-edge technologies, and practical methodologies in the domain of Automation and Robotics, with applications spanning industrial, medical, domestic, and defense sectors.

Designed for motivated and eligible candidates, the curriculum focuses on the design, development, and control of advanced intelligent systems, preparing students for innovative roles in the rapidly evolving field of Robotics and Automation.

Eligibility:

- This programme is offered under the sponsorship category for officers of the Indian Armed Forces (Army, Navy, and Air Force), Indian Coast Guard, DRDO scientists, and personnel from Indian Ordnance Factories and various Defence PSUs (such as HAL, BEL, BDL, etc.). It is also open to foreign nationals from countries approved by the Government of India, as well as to self-sponsored eligible candidates.
- This programme is open under the scholarship category to civilian students from relevant engineering disciplines who possess a valid GATE score in Mechanical Engineering, Computer Science and Information Technology, Electronics and Communication Engineering, Electrical Engineering, Aerospace Engineering, Instrumentation Engineering, Production and Industrial Engineering, Biomedical Engineering, Data Science & Artificial Intelligence or other disciplines relevant to Automation and Robotics.

Organization: The M.Tech in Automation and Robotics is a four-semester postgraduate programme. The first semester includes six core courses and one laboratory component. In the second semester, students undertake two core courses, two departmental electives, one open elective, and a laboratory component. Each course is evaluated through two internal assessments as part of continuous evaluation and an end-semester examination.

The dissertation work begins in the third semester, culminating in a Phase I evaluation at the end of the semester. In the final semester, students are required to submit their thesis and present their project work, which is evaluated by both internal and external examiners.

Program Structure

Semester I

Sl. No	Course Code	Course Title	Contact Hours/ Week		*Credits
			L	T/P	
1.	SR 601	Mathematics for robotics	3	0	3
2.	SR 602	Robotics-I	3	0	3
3.	SR603	Robot vision and perception	3	0	3
4.	SR 604	Control Engineering	3	0	3
5.	SR605	Essential concepts for Robotics	3	0	3
6.	SRPE I	Professional Elective-I	3	0	3
7.	PGC-601	Research Methodology and IPR	2	0	2
		Total	20	0	20

Semester II

Sl. No	Course Code	Course Title	Contact Hours/ Week		*Credits
			L	T/P	
1	SR606	Robotics-II	3	0	3
2	SR 607	Robotic Path planning	3	0	3
3	SRPE II	Professional Elective-II	3	0	3
4	SRPE III	Professional Elective-III	3	0	3
5	SRPE IV	Professional Elective-IV	3	0	3
6	SRR01L	Robotics Laboratory	0	6	3
7	PGC-602	Personality Development	2	0	2
		Total	17	6	20

* Four-week industrial practice school during summer vacation for scholarship students (optional).

Semester III

Sl. No	Course Code	Course Title	Contact Hours /week		*Credits
			L	T/P	
1	SR651	M.Tech. Dissertation Phase I	40**		20
		Total	40		20

Semester IV

Sl. No	Course Code	Course Title	Contact Hours /week		*Credits
			L	T/P	
1	SR652	M.Tech. Dissertation Phase II	40**		20
		Total	40		20

* 1 Credit in Theory/Tutorial means 1 contact hour and 1 credit practice/Project Thesis means 2 contact hours in a week.

****Contact Hours/ week**

List of Professional Electives

Sl. No	Course code	Course name
1	SR 608	Advanced control system
2	SR 609	Real time embedded system
3	SR 610	Legged Robotics
4	SR 611	Aerial Robotics
5	SR 612	AI /ML for Robotics
6	SR 613	Robot Programming
7	SR 614	Swarm Robotics
8	SR 615	Soft Robotics
9	SR 616	Deep Learning Theory and Practices
10	SR 617	HRI
11	SR 618	Underwater Robotics

Syllabus

Course Code	Course Name	L – T – P	Credits
SR 601	Mathematics for Robotics	3-0-0	3

Course Objectives:

- To provide a strong foundation in linear algebra, calculus, and differential equations relevant to robotics.
- To enable students to understand Probability theory and graph theory.
- To apply numerical methods in solving robotics-related mathematical problems.

Unit I: Vectors, dot and cross products, vector spaces, basis and dimension, Matrix operations: addition, multiplication, transpose, inverse, Eigenvalues, eigenvectors, diagonalization Gradient, divergence, curl, and Hessian.

Unit II: Set theory, and graph theory Probability theory, Bayesian theorem, Stochastic process, Markov theorem.

Unit III: Multivariable functions, partial derivatives Total derivative, chain rule, Ordinary differential equations: first- and second-order systems Introduction to numerical integration (Euler, Runge-Kutta methods), Linear and nonlinear Mapping.

Unit IV: Inverse function theorem and conditions for invertibility Singularities and rank deficiency of Jacobian. Integration.

Unit V: Introduction to optimization: objective functions, constraints Unconstrained and constrained optimization (Lagrange multipliers) Least-squares solutions, pseudoinverse Basics of numerical linear algebra: LU, QR decompositions.

Course Outcomes: After completing this course, the students will be able to:

CO1: Classify different types of robots and explain their components and specifications.

CO2: Describe kinematic systems and apply transformation matrices in robotic systems.

CO3: Solve inverse kinematics problems and analyze the Jacobian of serial link manipulators.

CO4: Plan and implement trajectory paths for robots using various motion profiles and programming techniques.

Textbooks:

1. Richard M. Murray, Zexiang Li, S. Shankar Sastry, A Mathematical Introduction to Robotic Manipulation, CRC Press, 1994.
2. Gilbert Strang, Introduction to Linear Algebra, Wellesley-Cambridge Press, 2016.
3. Erwin Kreyszig, Advanced Engineering Mathematics, Wiley, 10th Edition, 2011.
4. Ferrar, W. L. (1972). Linear Algebra. By K. Hoffman and R. Kunze. Pp. viii, 407. 1971.(Prentice-Hall.). *The mathematical gazette*, 56(397), 262-263.

Reference Books: 1. Peter Corke, Robotics, Vision and Control, Springer, 2017. 2. Jean Gallier, Geometric Methods and Applications, Springer, 2011. 3. Mark W. Spong, Seth Hutchinson, M. Vidyasagar, Robot Modeling and Control, Wiley, 2006. 4. Howard Anton, Elementary Linear Algebra, Wiley, 11th Edition, 2013. 5. Thomas and Finney, Calculus and Analytic Geometry, Pearson Education, 2003.

Course Code	Course Name	L – T – P	Credits
SR 602	Robotics-I	3-0-0	3

Course Objectives: · Understand various types and components of robots and their applications. · Learn about robot work cells, kinematic systems, and spatial descriptions using transformations and matrices. · Study inverse kinematics, Jacobina and the relationship between velocity, acceleration, and velocity propagation in robots. · Understand trajectory planning, motion profiles, and path generation for robotic mechanisms.
Unit I: Introduction to Robotics, Laws of Robotics, Types and components of Robot Anatomy, Robot terminology- Links, joints, Robot classification-based on motion, Robot classification -configuration. Unit II: DOF, Specification of a robot, work volume, workspace, work object, Robot geometrical configuration (PPP, RPP, RRP, RRR, etc.) & Selection of Robots, Control Resolution & Spatial Resolution. Unit III: Robot work cell, Kinematic systems, spatial descriptions: Position, orientation and frames, Coordinate frames, Mapping between frames (D-H method and DH free notations), translations, rotations and transformations matrices and Homogeneous Transformation Matrix, serial and parallel manipulators.

Unit IV: Inverse Kinematics of Serial and parallel manipulators-geometric method, Analytical method, velocity, velocity propagation, Jacobian, acceleration, Jacobian-force relationship, Robot Dynamics, Inertia properties.

Unit V: Trajectory Planning Definition, Introduction to Trajectory planning, General consideration in path description and Generation of motion. Point to point: Straight line path, Trapezoidal motion profile and S curve motion. Polynomial via point Trajectories.

Course Outcomes: After completing this course, the students will be able to:

CO1: Classify different types of robots and explain their components and specifications.

CO2: Describe kinematic systems and apply transformation matrices in robotic systems.

CO3: Solve inverse kinematics problems and analyze the Jacobian of serial link manipulators.

CO4: Plan and implement trajectory paths for robots using various motion profiles and programming techniques

Textbooks:

1. R. Deb, Robotics Technology and flexible automation, Tata Mc Graw Hill publishing company Ltd.
2. John J Craig, Introduction to Robotics-Mechanics and control, Pearson publication, 2008
3. S K Saha, Introduction to Robotics, McGraw Hill Education (India) Private Ltd, 2014.
4. R K Mittal, I J Nagrath, Robotics and Control, McGraw Hill Education (India) Private Ltd, 2003.

Reference Books:

1. Francis N. Nagy, Andras Siegler, Engineering foundation of Robotics, Prentice Hall Inc., 1980.
2. M.P. Groover, Mitchel Weiss, "Industrial Robotics: Technology, Programming and Applications"(2e), McGraw Hill, 2012
3. Richard D. Klafter, Thomas. A, ChriElewski, Michael Negin, "Robotics Engineering an Integrated Approach", Prentice Hall of India Pvt. Ltd., 1989
4. Carl D. Crane and Joseph Duffy, "Kinematic Analysis of Robot manipulation", Cambridge University press, 1998.
5. Yoram Koren, "Robotics", McGraw Hill, 1992.
6. K. C. Jain and Agarwal L. N. "Robotics Principles and Practice", Khanna Publishers, 1997.
7. Yu Kozihev, "Industrial Robots Handbook", MIR Publications, 1997.
8. D K Pratihari, Fundamentals of Robotics, Narosa Book publisher, 2017

Course Code	Course Name	L – T – P	Credits
SR 603	Robot Vision	3-0-0	3

Course Objectives:

- Understand the architecture and components of robotic vision systems, including image acquisition and processing techniques.
- Learn the principles of image acquisition, analysis, and the components involved in vision systems, such as basic optics and radiometry.
- Explore various image enhancement and analysis techniques, including noise removal, segmentation, and feature extraction.
- Study 3D vision concepts, including perspective projection geometry, camera calibration, and 3D reconstruction methods.
- Understand motion estimation, tracking techniques, and their applications in robotic vision systems.

Unit I: Architecture of Robotic vision system, vision system components, basic optics, basic radiometry, image formats, image noise, image representation, colour space, conversion of colour spaces.

Unit II: Image acquisition, representation, processing Data Acquisition and digitization, Conversion, Transmission and Processing, Laser Scanners 2D and 3D, Robot Vision, 3D cameras, filters for removal of noise.

Unit III: Image pre-processing, Image enhancement, operations on images, noise removal, segmentation, thresholding, edge detection algorithms, morphological operations, image analysis coding and representation of regions, dimensional analysis, feature extraction Fourier transformations, spatial domain techniques, Lossless and lossy image compression, image scaling, standard video formats.

Unit IV: 3D vision: Perspective projection geometry, pinhole camera model, lens distortion, affine and metric geometry, 2d and 3d geometrical transformations, intrinsic and extrinsic camera parameters, calibration methods, stereovision, epipolar geometry, triangulation, rotational matrix, fundamental matrix, stereo correspondence algorithms, feature based and correlation based.

Unit V: Motion estimation and tracking: Optical flow estimation, the concept of sensor fusion - Kalman filter, Simultaneous Localization and Mapping (SLAM) fundamentals, object tracking with Kalman filtering, feature extraction & object recognition Case studies/application.

Course Outcomes: After completing this course, the students will be able to:

CO1: Describe the architecture of robotic vision systems and explain the processes of image acquisition, data conversion, and processing.

CO2: Understand and apply the principles of image acquisition, analysis, and preprocessing, including basic optics and image representation.

CO3: Perform image processing techniques for image enhancement and analysis such as segmentation, edge detection, and feature extraction.

CO4: Apply 3D vision concepts for motion estimation and 3D reconstruction.

Textbooks:

1. Milan Sonka, Vaclav Hlavac, Roger Boyle, Image Processing, Analysis and Machine Vision”, (2/e), 1998.
2. E.R. Davies, Royal Holloway, Machine Vision: Theory, Algorithms and Practicalities, (3/e), University of London, December 2004.
3. R. Jain, R. Kasturi, B. G. Schunck, Machine Vision, McGraw-Hill, New York, 1995.
1. 4. P.A. Janaki Raman, Robotics and Image Processing an Introduction, Tata Mc Graw Hill Publishing company Ltd., 1995.

Reference Books:

1. Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing, (2/e), Pearson education, 2003.
2. 2. Boguslaw Cyganek& J. Paul Siebert, An Introduction to 3D Computer Vision Techniques and Algorithms, Wiley, 2009.

Course Code	Course Name	L – T – P	Credits
SR 604	Control Engineering	3-0-0	3
• Course Objectives: • Understand automatic control systems: types, performance specs, design process, block diagrams, Laplace transform, transient analysis, closed-loop/open-loop systems. • Model mechanical, electrical, hydraulic systems with block diagrams, analyze motor transfer functions, use block diagram reduction techniques, signal flow graphs. • Analyze time response: standard test signals, transient response for first/second-order systems, time domain specs, stability, steady-state error with Routh-Hurwitz criterion. • Study frequency response: domain specs, polar plots, Nyquist criteria, stability analysis with Nyquist plots, gain margin, phase margin, root locus technique for stability. • Explore control actions: discrete, proportional, integral, differential control actions, characteristics, limitations of comparators, actuators, amplifiers, servo motors, control valves. • Implement control systems: pneumatic, hydraulic, electrical, microprocessor-based systems, PLCs, microcontrollers, network-based distributed control systems.			

Unit I: Automatic Control System: definition, types and order of the system, performance specifications, Design process, Block diagrams, Laplace transform and transient analysis, closed and open loop systems. Feedback and Feed forward control system. Unit II: Modelling of Mechanical, Electrical, hydraulic system block diagram representations, Transfer functions. Block diagram reduction techniques, signal flow graphs. Unit III: Time response analysis, Standard test signals, Static and Dynamic Characteristics of Control Systems- Transient Response for First and second order systems. Time domain specifications, Stability Analysis, Routh Hurvitz criterion. Unit IV: Frequency domain controller analysis and design, compensators, P, PI, PD, PID controllers, state space analysis, State model for LTI system, Diagonalization, State equation, transition matrix. Unit V: Controllability and observability, Pole placement with state feedback, Pole placement with output feedback and Case Studies.
Course Outcomes: After completing this course, the students will be able to: CO1: Describe the architecture of robotic vision systems and explain the processes of image acquisition, data conversion, and processing. CO2: Understand and apply the principles of image acquisition, analysis, and preprocessing, including basic optics and image representation. CO3: Perform image enhancement and analysis using techniques such as segmentation, edge detection, and feature extraction. CO4: Apply 3D vision concepts, including camera calibration, stereovision, and 3D reconstruction, to robotic vision systems. CO5: Implement motion estimation and tracking techniques, including sensor fusion and object recognition, in robotic vision applications.
Textbooks: 1. Ogata, K., “Modern Control Engineering”, 5th Ed., Prentice Hall of India, 2013. 2. Kuo, B.C., “Automatic Control System”, 5th Ed., Prentice Hall of India, 1995. 3. Raven, F.H., “Automatic Control Theory”, 5th Ed., McGraw Hill, 1995
Reference Books:

1. Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing, (2/e), Pearson education, 2003.
2. Boguslaw Cyganek & J. Paul Siebert, An Introduction to 3D Computer Vision Techniques and Algorithms, Wiley, 2009.

Course Code	Course Name	L – T – P	Credits
SR 605	<i>Essential concepts for Robotics</i>	3-0-0	3

Course Objectives:

- To provide foundational understanding of physical principles, mechanical systems, sensors, actuators, electronics, and computing essential for robotics.
- To familiarize students with machine elements, electric drives, and control methods for robotic applications.
- To introduce key concepts in motion estimation, for robotic guidance and interaction.
- To develop practical knowledge in the selection and integration of components used in robotic systems.

Unit I Physical Principles: Force and Torque, Motion, Newton's Law of Motion, Momentum and Conservation of Momentum, Work, Power and Energy.

Unit II Simple Machines: The Inclined Plane, Screw Jack, Gears, Belts and Pulleys, Lever, Wedge, Efficiency of Machines.

UNIT III: Overview of semiconductor devices: BJT, MOSFET, SCR, TRIAC, photodiodes. Power supplies, signal amplification, active filters, op-amp applications. Number systems, logic gates, Boolean algebra, flip-flops, multiplexers. ADC/DAC, digital multimeters, frequency counters. Drive control: electric braking, duty cycles, speed/position control. Electric drives: components, multi-quadrant operation, torque equations.

Unit IV: Introduction to sensors, Principles of transduction and common conversion methods. Sensor characteristics, calibration, signal conditioning. Industrial sensors: encoders, LVDT, potentiometers, Hall-effect, proximity, ultrasonic, optical, GPS, IMU, LIDAR, RADAR. Smart sensors and shape memory materials.

Unit V: Introduction to actuators, Electric actuators: construction and working. DC motors, servo motors, stepper motors, BLDC, switched reluctance motors. AC machines: induction and synchronous motors, torque-speed characteristics. AC machines: induction and synchronous motors. Electric drives: components, multi-quadrant operation.

Course Outcomes: After completing this course, the students will be able to:

- CO1:** Apply mechanical principles and analyze basic machine elements relevant to robotics.
CO2: Understand and integrate sensors, actuators, and mechanisms in robotic systems.
CO3: Analyze electric drives and select suitable power systems for robotic actuation.
CO4: Utilize electronics and computing fundamentals for robotic control and interfacing.

Textbooks:

1. Mikell P. Groover, *Automation, Production Systems, and Computer-Integrated Manufacturing*, Pearson. (Covers fundamentals of automation, sensors, actuators, and industrial robotics applications)

2. Irving H. Shames & GK Mohana Rao, *Engineering Mechanics: Statics and Dynamics*, PEARSON Education, 2006.
3. John J. Craig, *Introduction to Robotics: Mechanics and Control*, Pearson. (Standard text for robotic kinematics, mechanisms, and dynamics)
4. D.K. Cheng, *Fundamentals of Engineering Electromagnetics*, Pearson. (Useful for understanding sensors and electromagnetic actuators like BLDC, Hall effect sensors)
5. R. K. Rajput, *Electrical Machines*, Laxmi Publications. (Detailed coverage of AC, DC, and special electric machines and drive systems)
6. R. S. Sedha, *A Textbook of Applied Electronics*, S. Chand. (Essential for analog/digital electronics, op-amps, and signal processing circuits)
7. J. David Irwin and R. Mark Nelms, *Basic Engineering Circuit Analysis*, Wiley. (Foundational concepts in circuits, signal conditioning, and measurement systems)

Reference Books:

1. W. Bolton, *Mechatronics, Electronic Control Systems in Mechanical and Electrical Engineering*, Pearson. (Excellent interdisciplinary reference combining electronics, mechanics, and control)
2. Ghosh, A. and Mallik, A.K., *Theory of Mechanisms and Machines*, East-West Press. (Authoritative text on kinematics, linkages, cams, gears, and machine elements)
3. R. Krishnan, *Electric Motor Drives: Modeling, Analysis, and Control*, Prentice Hall. (Focuses on modeling and control of electric motors in drive systems)
4. Siegwart, R., Nourbakhsh, I. R., & Scaramuzza, D., *Introduction to Autonomous Mobile Robots*, MIT Press. (For motion estimation, localization, SLAM, and vision-based robotic systems)
5. Simon Haykin, *Kalman Filtering and Neural Networks*, Wiley. (Detailed treatment of Kalman filtering and its application in sensor fusion)
6. Gonzalez, R. C., & Woods, R. E., *Digital Image Processing*, Pearson. (Key reference for vision systems and image processing applications in robotics)
7. Shingley, J.E. *Theory of Machines and Mechanisms*, 4th Edition, Oxford University Press; 2014.
8. P. Beer & Johnson, *Vector Mechanics for Engineers: Statics and Dynamics*, Tata McGraw Hill, New Delhi, 2001.
9. Thomas Bevan, *Theory of machines*

Course Code	Course Name	L – T – P	Credits
PGC601	PGC	3-0-0	3

Unit I: Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations.

Unit II: Effective literature studies approaches, analysis Plagiarism, Research ethics.

Unit III: Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee.

Unit IV: Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Unit V: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology, Patent information and databases. Geographical Indications.

Unit VI: New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Course Outcomes: After completing this course, the students will be able to:

CO1: Understanding the fundamentals of research and its methodology

CO2: Choose the appropriate research design and develop an appropriate research hypothesis for a research project

CO3: Knowledge of manuscript preparation, patents, and Intellectual property

CO4: Technology transfer and application of IPR in various domains

Text/Reference Books:

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students"

2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction" "Ranjit Kumar, 2nd Edition, "Research Methodology: A Step-by-Step Guide for beginners"

3. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.

4. Mayall, "Industrial Design", McGraw Hill, 1992.

5. Niebel, "Product Design", McGraw Hill, 1974.

6. Asimov, "Introduction to Design", Prentice Hall, 1962.

7. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.

Course Code	Course Name	L – T – P	Credits
SR 606	<i>Robotics-II</i>	3-0-0	3
Course Objectives: - To model and analyze robotic manipulators using classical and modern dynamic formulations. - To understand control strategies for trajectory tracking, regulation, and force interaction in robotic systems. - To explore nonlinear control methods applicable to under-actuated and constrained robotic systems.			
Unit I: Introduction to Rigid body dynamics: force, inertia, momentum, and energy, Position, velocity, and acceleration. Relative motion and rotating frames. Rigid body motion: translation, rotation about a fixed axis, and general plane motion.			
Unit II: Derivation of equations using Lagrange-Euler and Newton-Euler methods. Dynamic modelling of manipulators with actuators. State-space representations of planar robot systems.			
Unit III: Set-point regulation and trajectory tracking problems. Linear controllers: model-based controller, and feedforward designs. Actuator saturation, integrator wind-up, and anti-windup compensation.			
Unit IV: Nonlinear system behaviour, equilibrium, and perturbation, Lyapunov stability criteria. Feedback linearization, robust control, sliding mode control. Saturation-type controllers and variable structure systems.			
Unit V: Inverse dynamics and computed torque control. Force control and stiffness control principles. Hybrid position/force control. Impedance control and compliant motion. Reduced-state modelling.			
Course Outcomes: After completing this course, the students will be able to:			
CO1: Formulate and derive dynamic models of robotic manipulators using Newton-Euler and Lagrangian methods. CO2: Design and implement control strategies for regulation and trajectory tracking in robotic systems. CO3: Apply nonlinear control techniques ensuring system stability and robustness. CO4: Implement force and impedance control for interaction tasks in structured and unstructured environments.			
Textbooks: - Francis N-Nagy Andras Siegler, Engineering foundation of Robotics, Prentice Hall Inc., 1987 - John J. Craig, Introduction to Robotics Mechanics and Control, Second Edition, Addison Wesley Longman Inc. International Student edition, 1999 - M.P. Groover, Mitchel Weiss, “Industrial Robotics: Technology, Programming and Applications”(2e), McGraw Hill, 2012			
Reference Books: Robert J. Schilling, Fundamentals of Robotics Analysis and Control, Prentice Hall of India Pvt. Ltd., 2000			

2. Richard D. Klafter, Thomas. A, Chmielewski, Michael Negin, Robotics Engineering an Integrated Approach, Prentice Hall of India Pvt. Ltd.,1989.
3. M. W. Spong and M. Vidyasagar, Robot Dynamics and Control, John Wiley & Sons, NY, USA, 2004 11
1. P.A. Janaki Raman, Robotics and Image Processing an Introduction, Tata Mc Graw Hill Publishing company Ltd.,1995
2. Bernard Hodges, Industrial Robotics, Jaico Publishing house, 2nd Edition,1993.
3. Tsuneo Yohikwa, Foundations of Robotics Analysis and Control, Prentice Hall of India Pvt. Ltd.,2001.
4. 7. Bijay K.Ghosh, NingXi,T.J.Tarn, Control in Robtics and Automation Sensor-Based integration, Academic Press,1999

Course Code	Course Name	L – T – P	Credits
SR 607	Robotic path planning	3-0-0	3

Course Objectives:

- To introduce key concepts of path and motion planning for autonomous robots.
- To learn how robots navigate in known, unknown, or dynamic environments.
- To apply classical graph-based, sampling-based, and modern planning techniques.
- To understand planning under constraints such as obstacles, uncertainty, and multiple agents.

Unit I: Path planning vs. motion planning vs. trajectory planning. Types of planning problems: static/dynamic, discrete/continuous, deterministic/probabilistic. Configuration space (C-space), degrees of freedom, free space vs. obstacle space. Geometric representations: visibility graphs, roadmaps, cell decomposition. Holonomic vs. non-holonomic systems, Bug0, Bug1, Bug2, Tangent bug.

Unit II: Discrete representations using grids and graphs. Algorithms: Dijkstra, A*, Best-First Search. Dynamic and incremental search: D*, Anytime A*. Cost functions, heuristics, and performance trade-offs. Applications in 2D and 3D navigation.

Unit III: Random sampling of free space: PRM, Lazy PRM. Tree-based planners: RRT, RRT*, RRT-Connect. Nearest neighbour search, collision checking, Potential field theory.

Unit IV: Planning under sensor noise and map uncertainty. Obstacle avoidance in changing environments. Real-time re-planning for dynamic scenarios.

Unit V: Introduction to learning-based planning: Q-learning, policy learning. Using neural networks for path generation. Planning for multiple robots (multi-agent systems).

Course Outcomes: After completing this course, the students will be able to:

- CO1:** Describe and formulate robotic path planning problems using configuration space.
CO2: Apply graph-based algorithms like A* and D* for robot navigation.
CO3: Implement sampling-based planners like RRT and PRM.
CO4: Plan paths in uncertain or dynamic environments using probabilistic methods.

Textbooks:

1. **Steven M. LaValle, *Planning Algorithms***, Cambridge University Press (freely available at <http://planning.cs.uiuc.edu>).
2. **Choset, H. et al., *Principles of Robot Motion: Theory, Algorithms, and Implementations***, MIT Press.

Reference Books:

1. Siegwart, R., Nourbakhsh, I., & Scaramuzza, D. *Introduction to Autonomous Mobile Robots*, **MIT Press**.
2. Russell & Norvig, *Artificial Intelligence: A Modern Approach*, **Pearson**.
3. Research papers from IEEE ICRA, IROS, RSS, and NeurIPS on motion planning and learning-based approaches.
4. ROS Navigation Stack and Open Motion Planning Library (OMPL) documentation.

Course Code	Course Name	L – T – P	Credits
SRR01L	<i>Robotics Laboratory</i>	0-0-6	3

Course Objectives:

- To develop hands-on skills in image processing, control systems, robotic simulation, and AI-based optimization techniques.
- To implement and analyze classical and modern algorithms for control, planning, and swarm behaviors in robotic systems.
- To integrate sensor data fusion, path planning, and controller design for real-time applications in mobile and manipulator robots.
- To simulate and visualize kinematic, dynamic, and control properties of serial manipulators using MATLAB, RoboAnalyzer, and ROS.

1. Contrast stretching of a low contrast image, Histogram, and Histogram Equalization
2. Implementation of Image Smoothing Filters (Mean and Median filtering of an Image)
3. Implementation of image sharpening filters and Edge Detection using Gradient Filters
4. Implementation of PID and LQR controllers for unicycle system control.

5. Forward and Inverse Kinematics Analysis of Serial Manipulators using RoboAnalyzer
6. Real time Implementation and Analysis of Sensor Data Fusion.
7. Simulation of Robotic Manipulator Dynamics and Control using MATLAB.
8. Implementation of Classical Path Planning Algorithms on TurtleBot Waffle Pi using MATLAB/ ROS
9. Implement and simulate with animation the flocking behavior of a swarm using Reynold's model
10. Use ACO to solve travelling salesman problem for a given graph
11. Apply PSO algorithm for solving a 2D optimization problem

Course Outcome: After completing this course, the students will be able to:

- **CO1:** Apply image enhancement and edge detection techniques for robotic vision applications.
- **CO2:** Implement and compare classical and optimal control strategies (PID, LQR) for mobile robots.
- **CO3:** Analyze and simulate forward and inverse kinematics using RoboAnalyzer and MATLAB.
- **CO4:** Design and simulate path planning algorithms and swarm behaviors for multi-agent robotic systems using MATLAB/ROS.

Text book:

1. S. N. Sivanandam and S. N. Deepa, *Principles of Soft Computing*, Wiley India Pvt. Ltd.
2. R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, 4th ed., Pearson, 2018.
3. K. Ogata, *Modern Control Engineering*, 5th ed., Pearson Education, 2010.
4. J. J. Craig, *Introduction to Robotics: Mechanics and Control*, 4th ed., Pearson, 2017.
5. B. Siciliano and O. Khatib, *Springer Handbook of Robotics*, 2nd ed., Springer, 2016.
6. S. Russell and P. Norvig, *Artificial Intelligence: A Modern Approach*, 3rd ed., Pearson, 2010.
7. R. Siegwart, I. R. Nourbakhsh, and D. Scaramuzza, *Introduction to Autonomous Mobile Robots*, 2nd ed., MIT Press, 2011.
8. E. Şahin and W. M. Spears (eds.), *Swarm Robotics: SAB 2004 International Workshop*, Springer LNCS, vol. 3342, 2005.
9. M. Clerc (Ed.), *Particle Swarm Optimization*, ISTE Ltd and John Wiley & Sons, 2006.
10. M. Dorigo and T. Stützle, *Ant Colony Optimization*, MIT Press, 2004.

Course Code	Course Name	L – T – P	Credits
SR 608	<i>Advanced Control System</i>	3-0-0	3

Course Objectives: • Demonstrate non-linear system behavior by phase plane and describing function methods • Perform the stability analysis nonlinear systems by Lyapunov method • Develop design skills in optimal control problems • Derive discrete-time mathematical models in both time domain (difference equations, state equations) and z domain (transfer function using z-transform). • Predict and analyze transient and steady-state responses and stability and sensitivity of both open-loop and closed-loop linear, time-invariant, discrete-time control systems. • Acquire knowledge of state space and state feedback in modern control systems, pole placement, design of state observers and output feedback controllers			
UNIT I: State space Analysis State Space Representation, Solution of State Equation, State Transition Matrix, Canonical Forms, Controllable Canonical Form, Observable Canonical Form, Jordan Canonical Form. Tests For Controllability and Observability for Continuous Time Systems. UNIT II: Time Varying Case, Minimum Energy Control, Time Invariant Case, Principle of Duality, Controllability and Observability Form Jordan Canonical Form and Other Canonical Forms. Describing Function Analysis. UNIT III: Introduction to Nonlinear Systems, Types of Nonlinearities, Describing Functions, Describing Function Analysis of Nonlinear Control Systems. Phase-Plane Analysis Introduction to Phase-Plane Analysis, Method of Isoclines for Constructing Trajectories, Singular Points, Phase-Plane Analysis of Nonlinear Control Systems. UNITIV: Stability Analysis Stability in The Sense of Lyapunov., Lyapunov's Stability and Lyapunov's Instability Theorems. Direct Method of Lyapunov for The Linear and Nonlinear Continuous Time Autonomous Systems. Modal Control Effect of State Feedback on Controllability and Observability, Design of State Feedback Control Through Pole Placement. Full Order Observer and Reduced Order Observer. Calculus Of Variations Minimization of Functionals of Single Function, Constrained Minimization. Minimum Principle. Control Variable Inequality Constraints. Control And State Variable Inequality Constraints. Euler Lagrange Equation. UNIT V: Optimal Control Formulation of Optimal Control Problem. Minimum Time, Minimum Energy, Minimum Fuel Problems. State Regulator Problem. Output Regulator Problem. Tracking Problem, Continuous-Time Linear Regulators.			
Course Outcome: After completing this course, the students will be able to:			

CO1: Analyze time-varying and time-invariant linear systems using concepts of controllability, observability, and canonical forms. CO2: Apply describing function and phase-plane methods to evaluate the behavior of nonlinear control systems. CO3: Perform stability analysis of linear and nonlinear systems using Lyapunov's direct method. CO4: Design state feedback controllers and observers including full-order and reduced-order observers.
Text book: 11. H.K.Khalil, Nonlinear Systems, Prentice Hall 1996. 12. M. Gopal, <i>Modern Control System Theory</i>, 3rd ed., New Age International, 2012. 13. J.-J. Slotine and W. Li, <i>Applied Nonlinear Control</i>, Prentice Hall, 1991.
Reference book: 1. B. C. Kuo and F. Golnaraghi, <i>Automatic Control Systems</i>, 9th ed., John Wiley & Sons, 2009. 2. B. Friedland, <i>Control System Design: An Introduction to State-Space Methods</i>, Dover Publications, 2005. 3. A. E. Bryson and Y.-C. Ho, <i>Applied Optimal Control: Optimization, Estimation and Control</i>, Taylor & Francis, 1975. 4. B. D. O. Anderson and J. B. Moore, <i>Optimal Control: Linear Quadratic Methods</i>, Dover Publications, 2007. 5. Kirk, D.E., Optimal Control Theory: An Introduction, Prentice-Hall, 2004.

Course Code	Course Name	L – T – P	Credits
SR 609	<i>Real time embedded system</i>	3-0-0	3

Course Objectives: · Understand various types and components of robots and their applications. · Learn about robot work cells, kinematic systems, and spatial descriptions using transformations and matrices. · Explore various types of robot end effectors and grippers, their mechanisms, and design considerations. · Study inverse kinematics, robot dynamics, and the relationship between velocity, acceleration, and force in robots. · Understand trajectory planning, motion profiles, and path generation for robotic mechanisms.

Unit I: Embedded system architecture: microcontrollers vs. microprocessors. 8051 controller architecture/ARM, Bare-metal programming: GPIO, timers, interrupts, polling vs. interrupt-driven control. Finite state machines, control loop design. Sensor-actuator interfacing and real-time control logic. Unit II: Characteristics of real-time systems: soft vs. hard real-time, deterministic timing. RTOS architecture: task creation, scheduling (pre-emptive, cooperative), context switching. Task synchronization and communication: mutexes, semaphores, queues, mailboxes. Timer services, event flags, watchdog timers. Unit III: Linux architecture overview: kernel and user space. Processes, threads, and POSIX APIs. Real-time scheduling policies: SCHED_FIFO, SCHED_RR. Device driver basics and real-time I/O. Cross-compilation, build systems (Yocto/Build root), debugging tools (GDB, perf). Unit IV: Clock-driven and event-driven scheduling. Deadlock detection and prevention techniques, Rate Monotonic Scheduling (RMS), Earliest Deadline First (EDF). Task prioritization, jitter, latency, and deadline violations. Resource sharing protocols: Priority Inheritance, Priority Ceiling. Power-aware and memory-constrained design strategies. Unit V: Sensor fusion and real-time data acquisition. Real-time communication protocols: CAN, Modbus, I2C, SPI, UART.
Course Outcomes: After completing this course, the students will be able to: CO1: Design interrupt-driven embedded applications for real-time behaviour. CO2: Develop multitasking systems using RTOS concepts with inter-task synchronization. CO3: Implement and configure real-time features in embedded Linux environments. CO4: Apply scheduling theories to meet real-time constraints in software design.
Textbooks: 1. Edward A. Lee & Sanjit A. Seshia – <i>Introduction to Embedded Systems: A Cyber-Physical Systems Approach</i>, MIT Press. 2. Jane W. S. Liu – <i>Real-Time Systems</i>, Pearson. 3. Jonathan Valvano – <i>Embedded Systems: Real-Time Operating Systems for ARM Cortex-M Microcontrollers</i>, CreateSpace.
Reference Books: 1. Christopher Hallinan – <i>Embedded Linux Primer</i>, Prentice Hall. 2. Giorgio Buttazzo – <i>Hard Real-Time Computing Systems</i>, Springer. 3. Jack Ganssle – <i>The Art of Designing Embedded Systems</i>, Newnes. 4. FreeRTOS & Zephyr Project documentation (official websites).

Course Code	Course Name	L – T – P	Credits
SR 610	Legged robotics	3-0-0	3
Course Objectives:			

- Understand the principles of locomotion in legged systems including bipeds, quadrupeds, and hexapods.
- Analyze and model leg kinematics and dynamics for walking robots.
- Design motion planning, stability, and control strategies for legged robots.
- Explore sensors and actuators used in legged locomotion and terrain adaptation.
- Examine case studies of advanced legged robots and applications in defense, search & rescue, and healthcare.

Unit I: Introduction to locomotion types: crawling, walking, running, hopping, climbing, Comparison of wheeled vs legged mobility, biological basis: anatomy and motion of humans and animals, Classification: bipeds, quadrupeds, hexapods, and hybrid systems, Leg configurations: articulated legs, telescopic legs, parallel mechanisms.

Unit II: Kinematic chains and single leg modelling, Denavit-Hartenberg (D-H) parameterization for legs, Workspace analysis of limbs, Foot trajectory generation in Cartesian space, Gait cycle analysis: duty factor, stride length, phase shift, Inverse kinematics for foot placement and swing leg trajectories, ZMP.

Unit III: Gait generation for bipeds, quadrupeds, hexapods, Static and dynamic gait stability, Canonical gaits: crawl, trot, pace, bound, gallop, Gait transition strategies, Central Pattern Generators (CPG) and bio-inspired gait control, Timing synchronization and inter-leg coordination.

Unit IV: Environmental sensing using IMUs, LiDAR, vision, and foot sensors, Terrain classification and mapping, Footstep planning using terrain data, Reactive and proactive locomotion strategies, Online planning for rough, deformable, or unknown terrains, Motion planning with constraints: SLQ-MPC, RRT, A* for legged robots.

Unit V: Review of legged robots: Humanoid Robots, Boston Dynamics' Spot & Atlas, MIT Cheetah, ANYmal, Actuation technologies: SEA, PEA, electric, Current research trends and open challenges in legged robotics.

Course Outcomes: After completing this course, the students will be able to:

CO1: Understand principles of legged locomotion and biomechanical inspiration.

CO2: Model and analyse the kinematics and gait of legged robots.

CO3: Design and evaluate gait planning algorithms and balance strategies.

CO4: Apply control techniques for stability over various terrains and explore and analyse real-world legged robots in current research directions.

Textbooks:

1. Alexander, R. McNeill, *Principles of Animal Locomotion*, Princeton University Press, 2003.
2. Shuuji Kajita et al., *Introduction to Humanoid Robotics*, Springer, 2014.
3. Marc Raibert, *Legged Robots That Balance*, MIT Press, 1986.

Reference Books:

1. R. Playter, M. Raibert, and A. Buehler, "BigDog," in *Proc. SPIE 6230, Unmanned Ground Vehicle Technology VIII*, 2006.
2. H. Geyer, A. Seyfarth, and R. Blickhan, "Compliant leg behaviour explains basic dynamics of walking and running," *Proc. R. Soc. Lond. B*, vol. 273, no. 1603, pp. 2861–2867, 2006.
3. S. Kuindersma, R. Deits, M. Fallon et al., "Optimization-based locomotion planning, estimation, and control design for the Atlas humanoid robot," *Auton. Robots*, vol. 40, pp. 429–455, 2016.
4. **Jensfelt, P., & Leonard, J. *Simultaneous Localization and Mapping***, in Springer Handbook of Robotics. Specific chapter from Springer Handbook useful for SLAM systems in field robotics.
5. **Corke, P. *Robotics, Vision and Control: Fundamental Algorithms in MATLAB***, Springer, 2017. Hands-on guide for implementing vision, control, and perception tasks relevant to service robots.

Course Code	Course Name	L – T – P	Credits
SR 611	Aerial Robotics	3-0-0	3

Course Objectives:

- Understand the fundamental concepts and configurations of multi-rotor UAVs.
- Master reference frames, rotational matrices, and UAV kinematics for accurate motion analysis.
- Analyze UAV dynamics, including forces, moments, and six-degree-of-freedom equations.
- Explore sensors, actuators, and autopilot systems for longitudinal and lateral control.
- Develop skills in modeling LTI systems, analyzing time and frequency responses, and implementing vision-based navigation for waypoint following in UAV operations.

Unit I: Introduction of unmanned aerial robotics: fixed wing, Multi rotor, VTOL, different type of multi-rotor UAV configurations, applications and limitations of UAV configuration.

Unit II: Introduction to Cartesian coordinate, Reference frames, Rotational matrices-Euler axis rotation, terminologies on UAV and its components, UAV- kinematics.

Unit III: UAV-forces and moments, UAV dynamics, Six-degree-of-freedom equations of motion derivation, stability derivatives, trim conditions, linearization, longitudinal dynamics, lateral dynamics.

Unit IV: UAV sensors and actuators, longitudinal autopilot (pitch-rate damping, pitch hold, altitude hold, velocity hold), lateral autopilot (yaw-rate damping, roll hold, heading hold, coordinated turn, turn compensation)

Unit V: State-space model of LTI system, eigen value-eigenvectors, modelled composition, transfer function models, first and second-order systems, Pole placement, time response, frequency response, root locus, bode plot. Vision- based navigation, waypoint following.

Course Outcomes: After completing this course, the students will be able to:

C01: Demonstrate proficiency in configuring and operating multi-rotor UAVs, understanding kinematics and dynamics of 6DoF multirotor UAV. C02: Analysis and design of autopilot systems. C03: Modelling and analysis of LTI systems in frequency and time domain. C04: Implementation of vision-based navigation algorithms for real-time decision making
Textbooks: 1. Small Unmanned Aircraft: Theory and Practice, R. W. Beard and T. M. McLain, first edition. 2. Automatic control of aircraft and missiles, John H. Blakelock, second edition. 3. 3. Linear control systems: Analysis and Design, J. J. D'Azzo, C. H. Houpis and S.N. Sheldon, fifth edition.
Reference Books: 1. Modern Control Engineering, K. Ogata, fifth edition.

Course Code	Course Name	L – T – P	Credits
SR 612	<i>AI & ML for robotics</i>	3-0-0	3

Course Objectives: • Understand knowledge-based intelligent systems, rule-based expert systems, search methods, and effectively manage uncertainty in expert systems. • Introduce uncertainty, basic probability theory, Bayesian reasoning, and certainty factors as applied to rule-based expert systems. • Explore foundational concepts of machine learning, its applications, and understand the structure of artificial neural networks, including activation functions. • Study various machine learning approaches: unsupervised, supervised, semi-supervised, reinforcement learning, and their practical applications. • Introduce deep neural networks, specifically convolutional neural networks (CNNs), including operations like convolution, pooling, flattening, and CNN architecture design.
Unit I: Introduction to AI: Knowledge-based intelligent systems, rule based expert systems search methods-uncertainty management in rule-based expert systems, Introduction to uncertainty, basic probability theory, Bayesian reasoning, certainty factor.
Unit II: Foundation of machine learning, applications of machine learning, model of neuron in artificial neural networks, activation function, back propagation to train neural network.

Unit III: Overview of machine learning approaches: unsupervised, supervised, semi supervised, reinforcement LEARNING, Linear regression and classification: gradient descent, support vector machine, k nearest neighbor, and other classifiers.

Unit IV: Introduction of deep neural network, convolution neural network (CNN): convolution operations, pooling, flattening, building a CNN.

Unit V: Clustering: k-mean, self-organizing maps, other clustering algorithms, nature inspired algorithms, fuzzy logic. Introduction to Reinforcement learning. Applications of AI and ML techniques for solving problems in robotics especially in the area of Perception, Control and Manipulation. Nature inspired optimization algorithms, soft computing.

Course outcomes: After completing this course, the students will be able to:

CO1: Implement and evaluate knowledge-based and rule-based expert systems with proficient search methods and uncertainty management techniques.

CO2: Apply probability theory, Bayesian reasoning, and certainty factors to enhance rule based expert systems and decision-making processes.

CO3: Utilize foundational machine learning models and neural networks, implementing backpropagation for network training.

CO4: Implement and assess various supervised and unsupervised learning algorithms such as linear regression, SVMs, and k-nearest neighbors for classification tasks.

CO5: Design and optimize CNN architectures for image recognition and other complex pattern recognition tasks.

Textbooks:

1. Artificial Intelligence: a modern approach, Stuart Russell & Peter Norvig, Prentice Hall, 4th Edition, 2022.
2. Artificial Intelligence, E. Rich and K. Knight, 2nd ed., McGraw-Hill, New York, 1991.
3. Pratihari, D. K. (2013). *Soft computing: fundamentals and applications*. Alpha Science International, Ltd.

Reference Books:

1. An Introduction to Neural Network, J. A. Anderson, MIT Press, 1995.
2. Self-Organizing Maps, T. Kohonen, Springer.
3. Introduction to AI Robotics, Robin R. Murphy, MIT Press, 2000.

Course Code	Course Name	L – T – P	Credits
SR 613	Robot Programming	3-0-0	3

Course Objectives:

Unit I: Introduction to fundamentals of programming language, machine-level, assembly, high level languages, data types- declarations, constants, variables, operators and expressions, conditional expressions, programming structures, Input and Output functions, mechanics of running, testing and debugging.

Unit II: Robot software functions - coordinate systems, position control, control functions, subroutines, Online programming, off-line programming, advantages of off-line programming, lead through methods - powered lead through, manual lead through, teach pendant, Robot program as a path in space, defining position in space, motion interpolation, applications.

Unit III: Introduction to Robot operating system (ROS)- packages, launch files, understanding key concepts-services, actions and nodes, publisher, subscriber & messages, client, server, debugging of nodes, building robot environment, practice examples, sensor interfacing.

Unit IV: Basics of MATLAB and python programming, Introduction to Arduino, Interfacing of Arduino with MATLAB, parallel, serial, USB interfacing concepts, robot detection and movement control.

Unit V: Introduction to image processing, Image segmentation, Image enhancement, image arithmetic and logical operations, feature extraction, disparity map using stereo camera, optical flow-based object tracking, collision avoidance using mobile robot, object recognition, pose estimation.

Unit VI: Real time applications using Mobile robotics.

Course Outcomes: After completing this course, the students will be able to:

Textbooks:

1. M.P.Groover, "Automation, Production Systems and Computer Integrated Manufacturing", 5th Edition, Pearson Education, 2009.
2. John W. Webb and Ronald A. Reis, "Programmable Logic Controllers: Principles and Applications", 5th Edition, Prentice Hall Inc., New Jersey, 2003.
3. Krishna Kant, "Computer - Based Industrial Control", 2nd Edition, Prentice Hall, New Delhi, 2011.
4. Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", by Apress Berkeley, CA
5. Curtis D. Johnson, "Process Control Instrumentation Technology", 8th Edition, Pearson New International, 2013.
6. Lukas M.P, " Distributed Control Systems", Van Nostrand Reinhold Co., New York, 1986.

Reference Books:

1. N. Viswanandham, Y. Narahari, "Performance Modeling of Automated Manufacturing Systems", 1st Edition, 2009.
2. Stuart A. Boyer, "Introduction to SCADA Systems", ISA; 4th edition, October 2009.

3. A.K. Gupta and S.K. Arora ,"Industrial Automation and Robotics: An Introduction"; Mercury Learning & Information; Har/Cdr edition, February 2013.
4. Frank D. Petruzella, "Programmable Logic Controllers", 5th Edition, McGraw- Hill, New York, 2016.
6. Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat, "Industrial Internet of Things: Cyber manufacturing Systems" by Springer.

Course Code	Course Name	L – T – P	Credits
SR 614	Swarm Robotics	3-0-0	3

Course Objectives:

- Understand various Industrial and Defence applications of SWARM Robots.
- Understand and apply ACO and PSO for solving complex optimization problems
- Understand various algorithms in SWARM Intelligence and apply them in Swarm Robotic applications
- Study various Modelling and Simulation techniques used in SWARM robotics
- Understand various future applications and open research problems and challenges in Swarm Robotics

Unit I: Introduction to Swarm Intelligence, Swarm Robotics, Differences between Multi Robot Systems, Multi Agent Systems and Swarm Robotics. Application of Swarm Robotics, Features of Swarm robots, Scalability and Performance of Swarm (Amdahl's law, Gustafson's law, Universal Scalability law)

Unit II: Swarm Intelligence and other metaheuristic algorithms: Ant Colony Optimization and Particle Swarm Optimization. Apply SI to solve some of the NP hard problems like TSP

Unit III: Challenges/issues in applying SWARM robotics for practical problems. Robotic Hardware Platforms, Sensors, Odometry, SLAM, ROS introduction

Unit IV: Swam Behaviors: Aggregation, Dispersion, Pattern Formation, Flocking Behavior, Synchronization, Consensus, Area Coverage, Olfaction, Chaining, Clustering, Leader following. Stability and Convergence of Swarm behaviors e.g consensus control etc.

Unit V: Modelling and Simulation Aspects in Swarm Robotics: Rate Equation, Langevin, Fokker Planck equations, FSM, Graph Theory, Kuramoto Model, Potential Field Theory, Reynolds' Flocking Model. Different approaches for Task Allocations, Case study for energy optimization (dynamic task allocation) Swarm Robot Architectures, Human Swarm Interaction, Swarm Counter Measures. Collective Decision-Making models (Voter, Majority, Urn, Kuramoto, consensus models), RL and Deep Reinforcement Learning for Multi Agent Applications.

Course Outcomes: After completing this course, the students will be able to:

CO1: Apply metaheuristic algorithms in SI to solve computationally hard optimization problems CO2: Simulate and Implement different behaviors observed in animals and birds for Swarm Robotics applications CO3: Analyze how synchronization can be achieved using coupled oscillators model. CO4: Develop different Task allocation schemes using swarm intelligence principles.
Textbooks: 1. Swarm Intelligence. From natural to artificial systems. E. Bonabeau and M. Dorigo, 1999 2. Swarm Robotics: A formal approach, H. Hamann, 2018

Course Code	Course Name	L – T – P	Credits
SR 615	Soft Robotics	3-0-0	3

Course Objectives:

- To introduce the fundamentals of soft robotics, including definitions, applications, and bio-inspired design principles.
- To impart knowledge about the materials used in soft robotics, including polymers, elastomers, and advanced functional materials.
- To enable students to understand the design, modelling, actuation, and manufacturing techniques specific to soft robots.
- To develop an understanding of soft sensing, soft electronics, and their integration with control systems in soft robotic applications.
- To provide exposure to various real-world applications of soft robotics in grippers, artificial muscles, wearable devices, haptics, and medical devices.

Unit I: Introduction, Basics of robots, introduction to soft robotics: definitions and applications, Morphological computation and Bio inspired design, Advances in Soft Robotics.

Unit II: Materials for Soft Robotics, New Active soft materials to construct soft robots, Fundamentals of mechanics of polymer, polymers and application in soft robotics, Elastomer's thermoplastics and textile advanced material.

Unit III: Soft actuation (Design, modelling, manufacturing, and characterization), cable driven soft robots, fluidic actuation, electroactive polymer and dielectric elastomers, shape memory alloys, magnetostrictive materials, additional actuation strategies, fabrication and manufacturing of soft and smart materials.

Unit IV: soft electronics, soft sensing and control. How to embed sensing capabilities and conductive elements in soft structures, soft resistive, capacitive, and inductive sensing. Soft optical and ionic sensing, typical soft robot architectures, onboard powering, onboard control.

Unit V: FEM based modelling, Asymptotic modelling, Applications Soft grippers, artificial Muscles, wearables, haptic devices and medical devices.
Course Outcomes: After completing this course, the students will be able to: CO1: Describe the fundamental concepts of soft robotics, including its bio-inspired principles, morphological computation, and recent advancements. CO2: Analyze and select appropriate smart materials (e.g., polymers, elastomers, and textile-based materials) for soft robotic design based on their mechanical and functional properties. CO3: Design and evaluate soft actuators and sensors using various actuation mechanisms (fluidic, cable-driven, electroactive, SMA, etc.) and understand fabrication techniques for soft robotics components. CO4: Apply modeling techniques (e.g., FEM and asymptotic modeling) and implement sensing, powering, and control strategies for developing practical soft robotic applications such as grippers, artificial muscles, wearables, and medical devices.
Textbooks: 1. Soft Robotics: Trends, Applications and Challenges - Authors: Cecilia Laschi, Matteo Cianchetti 2. Biologically Inspired Robotics: Soft Gripping Systems - Author: Yunhui Liu et al. 3. Robotics, Vision and Control: Fundamental Algorithms in MATLAB -Author: Peter Corke
Reference Books: 1. Introduction to Autonomous Mobile Robots – Authors: Roland Siegwart, Illah Nourbakhsh, Davide Scaramuzza

Course Code	Course Name	L – T – P	Credits
SR 616	Deep Learning Theory and Practices	3-0-0	3
Course Objectives: • To introduce use to deep learning theory and its applications in robotics • To introduce artificial neural networks and their architecture • To introduce various techniques used for training artificial neural networks • To enable design and deployment of deep learning models for machine learning problems.			
Unit I: Representation power of feedforward neural network, limitations of shallow networks, why and when can deep networks avoid curse of dimensionality. Perceptron, convergence proof. Feedforward neural network, back propagation, loss surfaces, learning rates, optimization for deep networks: gradient descent (GD), momentum-based GD, Nesterov accelerated GD, stochastic GD, AdaGrad, RMSProp, Adam.			

Unit II: Bias variance tradeoff: overfitting and under-fitting. L2 regularization, early stopping, dataset augmentation, parameter sharing and tying, injecting noise at input, ensemble methods, dropout. Greedy layer wise pre-training, better activation functions, better weight initialization methods, batch normalization.

Unit III: Auto-encoders and relation to PCA, regularization in auto-encoders, denoising autoencoders, sparse auto-encoders, contractive auto-encoders, variational auto-encoders (VAEs), Word2vec and its relationship to latent semantic indexing (LSI).

Unit IV: Convolutional neural networks (CNNs), backpropagation in CNNs, LeNet, Alex Net, Inception, VGG, GoogLeNet, ResNet, Densenet. Recurrent neural networks, backpropagation through time (BPTT), vanishing and exploding gradients, truncated BPTT, stability, bidirectional RNNs, gated recurrent units (GRUs), long short-term memory (LSTM), solving the vanishing gradient problem with LSTMs.

Unit V: Encoder Decoder Models, Attention Mechanism, Hierarchical Attention, Transformers, Generative Adversarial Networks (GANs), LLM, VLM, Diffusion Models, Graph Neural Networks. Applications of deep learning theory in robotics.

Course Outcomes: After completing this course, the students will be able to:

CO1: Understand the theory and mathematics behind functioning of different types of artificial neural networks

CO2: Understand the use of different types of neural networks and their training methodologies.

CO3: Able to carry out design and implementation of deep learning models for NLP and image processing applications.

Textbooks/Reference book:

1. Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola, Dive into Deep Learning, 2021.
2. Ian Goodfellow and Yoshua Bengio and Aaron Courville, Deep Learning, MIT Press, 2016.

Course Code	Course Name	L – T – P	Credits
SR 617	HRI	3-0-0	3

Course Objectives: • Understand the fundamental theories, principles of Human-Robot Interaction. • Apply user-centered design methodologies and prototyping techniques for developing intuitive and effective HRI systems. • Evaluate HRI systems using both quantitative and qualitative methods. • Explore different interaction modalities (e.g., verbal, non-verbal, physical) and their effective application in HRI design.			
Unit1: Introduction to Human-Robot Interaction HRI Definition, goals. Key HRI paradigms and interaction styles (e.g., teleoperation, supervisory control, autonomy). Evolution of HRI. Limitations of HRI, Applications of HRI in different field of robotics			
Unit 2: HRI Design Principles and Methodologies Robot morphology and forms, Affordances, Design principles and patterns, Anthropomorphizing in HRI design, User-centered design process			
Unit 3: Interaction Modalities - Physical & Proxemic Interaction, Interaction Modalities - Robot motion, gestures, and body language. Proxemics: personal space and social distances in HRI Verbal & Non-Verbal Communication Spatial Interaction, Nonverbal Interaction, Functions of nonverbal cues in interaction, large language models, Natural Language Processing (NLP) for robot understanding and generation. Speech synthesis and recognition in robots. Robot perception of nonverbal cues Eye gaze, facial expressions, and auditory cues. Multimodal communication in HRI. Emotion and interaction			
Unit 4: Evaluating HRI Challenges in affective HRI, Quantitative Approaches Common HRI metrics: task performance, usability, user satisfaction, trust.			
Unit 5: Advanced Topics: Human-Robot Collaboration and Teaming, Human Swarm Interaction. Human Machine Teaming, Role of Shared Mental Models, Shared autonomy and mixed initiative control. Team coordination and communication in human-robot teams. Learning from demonstration and interactive learning. Applications in manufacturing (cobots), logistics, and space exploration. Role, benefits and challenges of AR/VR/XR in HRI. BCI, Leveraging Large Language Models in Human-Robot Interaction			
Course Outcomes: After completing this course, the students will be able to:			
CO1: Explain the historical development and current trends in HRI.			
CO2: Identify and differentiate between different types of robots and their interaction capabilities.			

CO3: Conduct user needs analysis and define design requirements for HRI scenarios.

CO4: Select and apply appropriate HRI design patterns and interaction techniques.

Textbooks/Reference books:

1. "Human-Robot Interaction: An Introduction" by Christoph Bartneck, Tony Belpaeme, Friederike Eyssel, Takayuki Kanda, Merel Keijsers, and Selma Šabanović. (Cambridge University Press, 2nd Edition, 2024).
2. D. Rodríguez-Guerra, G. Sorrosal, I. Cabanes and C. Calleja, "Human-Robot Interaction Review: Challenges and Solutions for Modern Industrial Environments," in *IEEE Access*, vol. 9, pp. 108557-108578, 2021
3. Sharkawy A-N, Koustoumpardis PN. Human–Robot Interaction: A Review and Analysis on Variable Admittance Control, Safety, and Perspectives. *Machines*. 2022; 10(7):591.
4. Nicole Robinson, Brendan Tidd, Dylan Campbell, Dana Kulić, Peter Corke, Robotic Vision for Human-Robot Interaction and Collaboration: A Survey and Systematic Review, *ACM Transactions on Human-Robot Interaction* (2023) Volume 12 Issue 1 Article No 12 pp 1-66
5. M. -Y. Lin, O. -W. Lee and C. -Y. Lu, "Embodied AI with Large Language Models: A Survey and New HRI Framework," *2024 International Conference on Advanced Robotics and Mechatronics (ICARM)*, Tokyo, Japan, 2024, pp. 978-983.
6. Atuhurra, Jesse. "Leveraging Large Language Models in Human-Robot Interaction: A Critical Analysis of Potential and Pitfalls." *arXiv preprint arXiv:2405.00693*, 2024.

Course Code	Course Name	L – T – P	Credits
SR 618	<i>Underwater Robotics</i>	3-0-0	3

Course Objectives:

- To introduce the foundational concepts, design types, and real-world applications of underwater robotic systems.
- To study the hydrodynamic modeling and control of underwater robots operating in a challenging environment.
- To explore underwater sensing, communication systems, localization, and autonomous mission planning.
- To understand propulsion and actuation mechanisms used in Autonomous and Remotely Operated Vehicles (AUVs/ROVs).

Unit1: Overview of underwater robotic systems: AUVs, ROVs, Hybrid Vehicles, History, current trends, and applications in exploration, surveillance, and monitoring, Environmental challenges: Pressure, drag, temperature, visibility, and communication constraints.

Unit 2: Coordinate systems and degrees of freedom in underwater vehicles, Rigid body dynamics and added mass, Hydrodynamic forces: Drag, lift, buoyancy, Equations of motion for underwater robots (6-DOF modeling).

Unit 3: Sensors: Pressure, sonar (active/passive), DVL, INS, depth and salinity sensors, Underwater cameras and optical sensors, Underwater acoustic communication and limitations, Modem technologies and navigation beacons.

Unit 4: Propulsion systems: Thrusters, propellers, biomimetic actuators, pump-jet propulsion, and vectored thrust. Actuation: Hydraulic, electric, and pneumatic actuators, Localization techniques: Dead reckoning, acoustic positioning, SLAM, Path planning in 3D environments, Motion control strategies: PID, backstepping, sliding mode, adaptive control, Autonomous decision-making and mission planning.

Unit 5: Mechanical and electrical design of underwater vehicles, Power systems and pressure housing, Launch and recovery systems, Case studies: Deep-sea exploration, defense missions, marine habitat mapping, offshore inspection.

Course Outcomes: After completing this course, the students will be able to:

CO1: Differentiate among various underwater robotic systems and describe their specific applications and constraints.

CO2: Derive and analyze dynamic models of underwater vehicles including hydrodynamic effects.

CO3: Select and evaluate appropriate underwater sensors and communication systems.

CO4: Design motion control strategies and path planning methods considering propulsion mechanisms and environmental limitations.

Textbooks/Reference books:

1. Yuh, J., & West, M. (2001). *Underwater Robotics*. Springer.
2. T. I. Fossen, *Guidance and Control of Ocean Vehicles*, Wiley, 1994.
3. R. B. Wynn et al., "Autonomous Underwater Vehicles: Current Activities and Research Opportunities," *Marine Technology Society Journal*, vol. 47, no. 5, pp. 17–23, 2013.
4. J. Jalving, K. Gade, O. Hagen, and K. Vestgård, "A toolbox of aiding techniques for the HUGIN AUV integrated inertial navigation system," in *Proc. of IEEE Oceans*, 2003.
5. H. Singh et al., "Seabed AUVs for Imaging and Mapping in Deep Water," *J. Field Robotics*, vol. 24, no. 6, pp. 419–436, 2007.
6. S. B. Williams and I. Mahon, *Autonomous Underwater Vehicles: Navigation and Control*, Springer, 2020.
7. F. Fanelli et al., *Underwater Communications and Networking*, Springer, 2019.
8. Y. Petillot, *Autonomy in Underwater Robotics*, Springer Handbook of Robotics, 2nd ed., Springer, 2016.

M. Tech. in Industrial Systems Engineering (Model Based Systems Engineering) for working professionals

About the Program: M. Tech. in Industrial Systems Engineering (Specialization in Model Based Systems Engineering) focuses on Systems Thinking, Systems Architecture, Systems Design, Modelling, Verification, Validation, AI/ML, Design Optimization etc. This program also puts emphasis on domains like Aerospace Systems/Automotive Systems /Medical Systems/ Embedded Software Systems Engineering.

Program Duration: 2.5 Years (5 semesters),

Mode of Conduct: Hybrid Mode

Eligibility:

1. **Degree:** B.E. / B. Tech. in any stream of Engineering / M.Sc. from a recognized Institute/University.
2. **Experience:** Two years professional experience in Systems Development. The candidate shall be currently employed. Candidate has to provide certificate from the employer to confirm his nature of work) and candidate has to provide NOC from their respective employer.

Classes:

- Classes and tutorials will be conducted through hybrid mode.
- Classes will be conducted on Friday Evening & Saturdays.
- All students have to be present at DIAT for one week at the beginning and two weeks at the end of 1st and 2nd semesters for lab classes / hands on training / tutorials / end semester exams. Students have to present at DIAT for two weeks at the end of 3rd to 5th semester to complete their thesis work report / thesis followed by presentation / end semester exams.

Examination/Evaluation:

Theory Courses:

- Two formative assessments during the semester with 20 marks each. (Online or Offline Mode)
- Assignments/Quizzes shall carry 10 marks.
- End Semester Examination shall carry 50 marks. Students have to appear for the End Semester exams at DIAT.

Dissertation Work:

- Students have to carry out their Dissertation work at their respective organisations.
- Students have to choose one Guide/Supervisor from their organisation and one from DIAT. The thesis topics shall be mutually agreed upon. Both the Supervisors/Guides will have to support and monitor the progress.
- Students have to submit Dissertation progress report in the 3rd and 4th semesters and Thesis in the 5th / Final Semester.
- At the end of the 3rd, 4th and 5th semesters, students have to appear for End Semester Examinations / Evaluation of submitted Report / Thesis, presentation on the completed work and a viva voce.

Program Structure

Semester-1

#	Course Code	Course Name	Credits
1	ISE 601	Introduction to Systems Engineering	3
2	ISE 602	Requirements Engineering	3
3	MOOC /SWAYAM NPTEL / PGC 603	Research Methodology	3
4	ISE 641	*Systems Engineering Lab - 1	2
		CREDITS FOR FIRST SEMESTER	11

Semester-2

#	Course Code	Course Name	Credits
1	ISE 603	System Architecture, Design & Tradeoff Analysis	3
2	ISE 604	Multi-Disciplinary Analysis & Optimization	3
3	MOOC /SWAYAM NPTEL / PGC 604	AI/ML	3
4	ISE 642	*Systems Engineering Lab - 2	2
		CREDITS FOR SECOND SEMESTER	11

Semester-3

#	Course Code	Course Name	Credits
1	ISE 605	Model Based Systems Engineering	3
2	ISE 606	System Verification & Validation	3
3		Professional Elective-1	3
4	ISE 651	M. Tech. Dissertation Phase I	10

		CREDITS FOR THIRD SEMESTER	19

Semester-4

#	Course Code	Course Name	Credits
1		Professional Elective-2	3
2		Professional Elective-3	3
3	MOOC/SWAYAM NPTEL	Professional Elective-4	3
	ISE 652	M. Tech. Dissertation Phase II	10
		CREDITS FOR FOURTH SEMESTER	19

Semester-5

#	Course Code	Course Name	Credits
1	ISE 653	M. Tech. Dissertation Phase III	20
		CREDITS FOR FIFTH SEMESTER	20

List of Professional Electives

#	Course Code	Course Name	C
1	ISE 607	Human Factors in Systems Engineering	3
2	ISE 608	System Safety & Reliability	3
3	ISE 609	Systems Life Cycle Cost Analysis & Risk Management	3
4	ISE 610	AI-ML for Systems Engineering	3
5		SWAYAM-NPTEL - MOOC	3
Electives of Specific Domain			

7	ISE 611	Spacecraft Systems Engineering	3
8	ISE 612	Aircraft Systems Engineering	3
9	ISE 613	Automotive Systems Engineering	3
10	ISE 614	Medical Systems Engineering	3
11	ISE 615	Software Systems Engineering	3

For Course: 1 credit is 1 lecture hour per week

For Laboratory: 1 credit is 2 hours laboratory work per week

Course Work: 40 Credits

Dissertation/Thesis: 40 Credits

Total Credits: 80

Note:

- *Systems Engineering Lab 1 & 2 will be conducted offline at DIAT, one week during the beginning of the semester and one week at the end of the semester.
- Students have to take minimum 1 or maximum 2 electives from the list of “Electives of Specific Domain”
- Students may opt MOOC/SWAYAM NPTEL course for Professional Elective - 4 in the fourth semester.

Syllabus

Course Code & Title
ISE 601 - Introduction to Systems Engineering
Course Context
Systems Engineering is an interdisciplinary approach that facilitates the successful realization of complex systems. As a critical discipline and practice, it has been instrumental in the development of many advanced and integrated systems across various domains. At its core, Systems Engineering involves a holistic view of a problem—considering all facets and variables, and effectively integrating both technical and social dimensions. Systems Engineers assume a variety of roles throughout a system's lifecycle, including Requirements Owner, Systems Architect, Systems Analyst, Systems Integrator, and Integrated Product Team (IPT) Coordinator. They serve as the <i>technical conscience</i> of a project, ensuring coherence, integrity, and alignment of the system with its intended purpose. In essence, Systems Engineers are the glue that binds the diverse elements of a system, enabling it to function as a unified and effective whole.
Course Objectives
1. Introduce systems engineering practice (theory) that pertain to creation of multi-disciplinary solutions to complex systems. 2. Build an appreciation and provide insights into key systems engineering practices. 3. Provide an overview of various development lifecycle activities pertaining to systems engineering of complex systems.
Course Content
Unit I: Fundamentals of Systems: Definition & Concepts of System, Systems Engineering, Systems Thinking, Structure of Complex Systems. Unit II: System Development Life Cycle Stages:

Requirement Definition, Conceptual Design, Preliminary Design, Architecture Definition, Detailed Design and Development, System Analysis, Interface, Management, System Integration, System Verification, System Transition, System Validation, System Operation, System Maintenance, System Disposal.

Unit III: Systems Engineering Management:

Technical reviews management. Development, Acceptance & Operational Test & Evaluation, Test & Evaluation Master Plan, Decision Management, Technical Risk Management, Configuration Management, Quality Assurance,

Unit IV: Systems Engineering Development Approaches:

Waterfall, V, Spiral models. Lean and agile Systems Engineering.

Unit V: Specialty Areas in Systems Engineering:

Interoperability, Logistics, Safety, Reliability, Maintainability, Security, Usability.

Unit VI: Modeling & Simulation:

Introduction to System Modeling & Simulation.

Course Outcome

CO1: Describe the system development process

CO2: Define the different concepts in systems engineering

CO3: Apply the concepts to build a system of interest

CO4: Design an architecture of a system of interest

CO5: Simulate a system of interest and analyze

Text Books

1. "Systems Engineering Principles and Practice" by Kossiakoff, Alexander and William N. Sweet, Wiley, 2011
2. "Systems Engineering Practice, Canberra: Argos Press" by Faulconbridge, R.I. and Ryan, M. J., Revised Edition 2018.

Reference Books / Materials

1. "INCOSE Systems Engineering Handbook", Ver. 4, Wiley.

2. “System Engineering Body of Knowledge”, www.sebokwiki.org.
3. “NASA Systems Engineering Handbook”, Rev1, December 2007.
4. “ISO/IEC/IEEE 15288 - Systems and software engineering — System life cycle processes”, 2023.
5. “Systems Engineering And Analysis” by Benjamin S. Blanchard and Wolter J. Fabrycky, 6th edition 2023, Prentice Hall International Series in Industrial and Systems Engineering.
6. System Engineering Analysis, Design, and Development: Concepts, Principles, and Practices, 2nd Edition Charles S. Wasson

Course Code & Title
ISE 602 – Requirements Engineering
Course Context
The complete and accurate definition of system requirements is a primary focus of the early systems engineering effort. The life cycle of a system begins with a mission statement. Subsequently, this is translated into a large number of statements of requirement that form the basis for the logical (functional) design and subsequently the physical architecture. The requirements flow down and transitions must be managed by a rigorous process that guarantees that all relevant requirements are included. It also needs to be ensured that all irrelevant requirements excluded. The establishment of correct and sufficient requirements is fundamental to the engineering of complex multidisciplinary systems
Course Objectives
1. Understand the processes and management practices associated with the requirements engineering discipline. 2. Understand the need for the requirements engineering discipline. 3. Understand the strengths and weaknesses of accepted requirements engineering methodologies and processes. 4. Develop major requirements engineering plans and artefacts. 5. Understand the role and contribution of requirements engineering in project and business contexts. 6. Develop appropriate requirements engineering artefacts for an example project.
Course Content
Unit I: Requirements Engineering Processes: Requirements Engineering Processes, Representation and Organization of Requirements, Implementation and Applications of Traceability, Capabilities of Commercial Requirements, Requirements Engineering in Problem/Solution Domain, Functional Breakdown, Concept of Operations, Types of Requirements. Unit II: Characteristics of Good Requirements: Requirements attributes, EARS Notation: Ubiquitous Requirements, Event-Driven Requirements, State-Driven Requirements, Optional Feature Requirements, Complex Requirements. Unit III: Requirements in Problem Domain & Solution Domain

Stakeholder Needs & Requirements, Requirements Elicitation, CONOPS, Operational Scenarios & Use cases, Requirements hierarchy & flow down, Requirements specification tree, Interface requirements,

Unit IV: Tools for Managing Requirements:

DOORS (Dynamic Object-Oriented Requirements System): Requirements Capture & Management, Traceability, Collaboration, Customization & Scripting, Integration with Other Tools, Version Control & Change Management.

MathWorks Tools.

Course Outcome

CO1: Define the principles of requirements capture and authoring

CO2: Describe the process of requirements capture and management

CO3: Apply the good requirements principles to a system of interest

CO4: Examine and review the requirements for a system of interest

CO5: Categorize the requirements into various types

CO6: Evaluate the design tradeoff during functional breakdown for a system of interest

Text Books

1. "Requirements Engineering" by Jeremy Dick, Elizabeth Hull and Ken Jackson, 4th edition, 2017

Reference Books / Materials

1. "Requirements Engineering: Fundamentals, Principles & Techniques", Klaus Pohl, 2nd edition, Springer, 2025
2. "INCOSE Needs & Requirements Manual", INCOSE Requirements Working Group, TP-2021-002-01, Wiley, 2024
3. "Requirements Practice", by Ryan, M. J., Canberra: Argos Press, 2017
4. "INCOSE - Guide for Writing Requirements" - V3, updated 2019
5. "System Engineering Analysis, Design, and Development: Concepts, Principles, and Practices", 2nd Edition Charles S. Wasson, 2015.

Course Code & Title
ISE 603 - System Architecture, Design & Tradeoff Analysis
Course Context
The purpose of System Architecture and Design is to enable the creation of a global solution based on principles, concepts and properties logically related and consistent with each other. The solution architecture and design have features, properties and characteristics satisfying the set of requirements, and implementable through technologies. An effective architecture is as design agnostic as possible to allow for maximum flexibility in design space. This course covers principles and methods for technical System Architecture. The background, history and some frameworks of system architecture are provided, and using the architecture framework consists of all views, operational view, systems view and technical view, some examples are explained. It presents a synthetic view including: the resolution of ambiguity to identify system goals and boundaries; the creative process of mapping form to function; and the analysis of complexity and methods of decomposition and re-integration. Industrial speakers and faculty present examples from various industries. Heuristic and formal methods are presented. Also, some of the recent advances in System Architecture are provided.
Course Objectives
1. Understand system architecture and design processes 2. Define various frameworks, methodologies and approaches for system architecture 3. Able to identify and arrive at the architecture of systems, critique them, and learn from them 4. Create architectures for new or improved systems 5. Execute the role of a system architect 6. Produce deliverables of the architect needed to define the architecture of a system
Course Content
Unit I: Architecture Fundamentals: Architecture Definition, Architecture Viewpoints, Concept Analysis, Models & Views of Architecture, Functional, Behavioral, Data, Performance, Case Studies Unit II: Architecture Evaluation and Analysis: Structure & Behavior, Evaluating Candidate Architectures, System/Subsystem Analysis, Tradeoff Analysis, Architecture Frameworks & Standards Unit III: Design Principles, Methodologies & Progression:

Structured & object oriented design approaches, Design Heuristics & principles, Reuse/modularity, Design Progression, Architecture Domains, Software, IT, Manufacturing, Social

Unit IV: Design For X:

Design for Reliability, Design for Manufacturability, Design for sustainability, Design of Experiments & sensitivity analysis Robustness Design, Tradeoff Analysis.

Unit V: Intellectual Property Considerations:

Patents & Intellectual Property

Course Outcome

CO1: Identify the different views

CO2: Describe the process of developing architecture

CO3: Sketch the different architectures for the system of interest

CO4: Calculate the parameters of interest from the system architecture

CO5: Develop a complete architecture for the system of interest.

CO6: Analyze and obtain an optimal architecture for a system of interest.

Text Books

1. "The Art of Systems Architecting", Mark W Maier & E. Rechtin, 4th edition, CRC Press, 2025

Reference Books / Materials

1. "System Architecture: Strategy, Product Development for Complex Systems", Edward Crawley, Bruce Cameron, Daniel Selva, 2nd edition, Pearson, 2023 "
2. "Systems and software engineering — Architecture description", ISO/IEC/IEEE 42010:2011
3. "IEEE Standard for Application and Management of the Systems Engineering Process" - 1220-2005
4. System Engineering Analysis, Design, and Development: Concepts, Principles, and Practices, 2nd Edition Charles S. Wasson, 2015.

Course Code & Title
ISE 604 - Multi-Disciplinary Analysis & Optimization
Course Context
The goal of multidisciplinary analysis & optimization (MDAO) is to find a solution to a multi-disciplinary problem within an optimization framework. The objective of the course is to learn methodologies for formulating and performing multi-disciplinary analysis, how to build surrogate models and uncertainty models and do system level optimization using decomposition strategies.
Course Objectives
1. Understand Multi-disciplinary Analysis and Challenges for Optimization 2. Learn about various Decomposition strategies for MDAO 3. Need for Surrogate Modeling and Variable Fidelity Analysis 4. Learn about various Optimization techniques and how to compute coupled derivatives and how to handle multiple objectives 5. How to handle uncertainty in the design process
Course Content
Unit I: Introduction Definition of Multi-disciplinary Analysis and Design Optimization (MDAO), Why MDAO?, Building blocks for MDAO, Challenges in Implementation, Parameterization of System, Variable Fidelity Analysis, Organizational Complexities Unit II: Types of MDAO Architectures Concept of coupled Design Variables, Monolithic MDAO Architectures, Distributed MDAO Architectures Unit III: Surrogate Modeling and Design Space Visualization Response Surface Methodology and DoE, Design and Analysis of Computer Experiments, Kriging, Deep Neural Networks, Design Space Visualization. Unit IV: Gradient Based Optimization and Computation of Derivatives Constrained Problem Formulation, understanding n dimensional space, Optimality conditions, Penalty Methods, Sequential Quadratic Programming, Gradients and Jacobians, Overview of

methods for computing derivatives, Symbolic Differentiation, Finite Differences, Complex Step, Algorithmic Differentiation, Adjoint Methods, Coupled derivatives computation

Unit V: Multi-Objective Optimization

Multiple Objectives, Pareto Optimality, Solution Methods

Unit VI: Optimization Under Uncertainty

Robust Design, Reliable Design, Building Uncertainty Models when Data is scarce

Unit VII: Frameworks for MDAO

Frameworks in Industry, Setting up MDAO problem in frameworks, Case Study

Course Outcome

CO1: Explain the principles of multi-disciplinary analysis and optimization and their applications in engineering and design.

CO2: Apply mathematical optimization techniques and computational algorithms for solving multi-disciplinary problems.

CO3: Implement and evaluate various optimization techniques, such as gradient-based methods, evolutionary algorithms, and surrogate modeling.

CO4: Be able to understand and translate the system requirements into a formal Optimization Problem using an appropriate multi-disciplinary analysis with high fidelity and solve the same

Text Books

1. "Engineering Design Optimization" by Joaquim R.R.A. Martins, Andrew Ning, Cambridge University Press, 2021
2. "A Summary of Industry MDO Applications and Needs," Giesing, J. P., Barthelemy, Jean-Francois M., AIAA Paper 98-4737 (1998).

Reference Books / Materials

1. "Response Surface Methodology: Process and Product Optimization using Designed Experiments" by Myers RH, Montgomery DC, Anderson-Cook CM, 4th Edition, John Wiley & Sons.
2. "Design & Analysis of Computer Experiments", by Jerome Sacks, William J Welch, Toby J Mitchell, Henry p. Wynn Statistical Science 4(4) 409-423 Nov 1989.
3. "Efficient Global Optimization of Expensive Black-Box Functions" by Donald R. Jones, Matthias Schonlau, William J Welch, Journal of Global Optimization 13, 455-492, 1998

4. “Algorithms for Optimization” by Mykel J Kochenderfer, Tim A Wheeler, The MIT Press - 9780262039420- EPUB publication

Course Code & Title
ISE 605 - Model Based Systems Engineering
Course Context
Model-based systems engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases. MBSE Formalizes the practice of systems development using models. It results in quality/productivity improvements & lower risk. Data-centric specifications enable automation and optimization, allowing SEs to focus on value added tasks and ensure a balanced approach is taken. Unprecedented levels of systems understanding can be achieved through integrated analytics, tied to a model-centric technical baseline.
Course Objectives
1. Appreciate the need and advantages of model-based approaches 2. Familiarity with SysML notation 3. Familiarity with various modeling approaches and methodologies 4. Develop various types of models pertaining to requirements, architecture and design of complex systems
Course Content
Unit I: Introduction to MBSE: Introduction to MBSE, MBSE Concepts, MBSE Ontology Unit II: Modeling Techniques and Languages: Introduction to Object Process Modeling (OPM), Object Process Language (OPL), Overview of SysML Block Definition Diagrams, Internal Block Diagrams, Use Case Diagrams, Activity Diagrams, Sequence Diagrams, State Machine Diagrams, Parametric Diagrams, Requirements Diagrams, Package Diagrams Unit III: Modeling Approaches: Operational Analysis Modeling, Functional Analysis Modeling, Logical Architecture Modeling, Physical Architecture Modeling Unit IV: Architecture Frameworks:

Unit V: Practical Applications and Case Studies:

Case Studies of MBSE, MBSE Deployment

Unit VI: Advanced Concepts:

Introduction to Digital Twins

Course Outcome

CO1: Describe the different modelling paradigms and diagrams

CO2: Apply the different modelling paradigms to the system of interest

CO3: Develop the model for the system of interest

CO4: Analyze the behavior of the models.

CO5: Evaluate the different design tradeoff from the models for the system of interest

Text Books

1. “SysML Distilled: A Brief Guide to the Systems Modeling Language”. Lenny Delligatti. Addison-Wesley Professional; 1 edition-2013
2. “Model-based systems engineering with OPM and SysML” by Dov Dori, Springer

Reference Books / Materials

1. “SysML for Systems Engineering – A model-based approach” by Jon Holt and Simon Perry, IET. 2013
2. “Model-based System and Architecture Engineering with the Arcadia Method (Implementation of Model Based System Engineering)”, by Jean-Luc Voirin, ISTE Press - Elsevier. 2017
3. “Handbook of Model-Based Systems Engineering”, Editors: Azad M. Madni, Norman Augustine, Michael Sievers, Springer 2023

Course Code & Title
ISE 606 - System Verification & Validation
Course Context
System verification & validation is critical to the success of engineered systems. It needs to be verified that the system design satisfies the system requirements. It needs to be validated that the system requirements meet the stakeholders needs. The aim is to test and evaluate the system progressively as it passes through the various development phases to avoid costly and time-consuming modifications to the system design late in the life cycle. Progressive test and evaluation is both a risk mitigation measure and project performance measure that provides a high degree of confidence early in the system life cycle that the design is tracking to perform as required. A thorough evaluation of a system involves validating the system against the original customer requirements. Obviously, this full validation cannot be completed until the entire system has been designed, developed and constructed, and then operated in the intended operational environment by operational personnel.
Course Objectives
1. Articulate importance and key aspects of verification/validation in Systems Engineering and Project Management as applied to system design and capability acquisition lifecycles 2. Appreciate validation methods, verification methods and categories, configuration baselines and functional and physical configuration 3. Compare the types of verification/ validation and their contemporary issues 4. Develop hierarchical and traceable verification/ validation measures for systems - measures of effectiveness/performance (MOEs/MOPs) 5. Understand and formal methods of verification
Course Content
Unit I: Fundamentals of System Verification and Validation: System Verification, System Validation, Various Approaches to System Validation and Verification, Inspection, Testing, Analysis, Demonstration Unit II: Test Case Generation: Generation of Test Cases Using the Markov Chain Model, Writing Verification/Validation Plans Unit III: Formal Methods: Introduction to Formal Methods, Formal Approaches to System Validation/Verification

Unit IV: Specialty Areas:

Focus on Specialty Areas (e.g., EMI/EMC) DO 160

Unit V: Test Automation:

Test Automation Models, Computation Automation, Timed Automation, Simulation

Unit VI: Model Checking Verification:

Model Checking Verification Techniques

Unit VII: Standards for Safety-Critical Systems:

Verification and Validation Activities Prescribed in Standards, DO-178C, DO-254, APR 4754

Course Outcome

CO1: Describe the various standards used in the verification process

CO2: Define the test methods for the system of interest

CO3: Design test cases for the system of interest

CO4: Evaluate the complexity of systems and identify the test effort

CO5: Develop a test plan for the system of interest.

Text Books

1. "Verification, Validation and Testing of Engineered Systems," by Engel, Avner, John Wiley & Sons, 2010
2. "Understanding Formal Methods" by Jean-Francois Monin, , Springer, 2003

Reference Books

1. "Understanding Formal Methods", by Jean-Francois Monin, , Springer, 2003
2. "Industrial Use of Formal Methods: Formal Verification" by Jean-Louis Boulanger (Editor), Wiley, 2012
3. "Evolving Toolbox for Complex Project Management" by Eds. Alex Gorod, Leonie Hallo, Vernon Ireland, Indra Gunawan (2019), CRC Press, Taylor & Francis Group, Auerbach, ISBN 9780429197079
4. "Test and Evaluation of Aircraft Avionics and Weapon Systems" by McShea, R. E (2010)., 2nd Ed., Institution of Engineering and Technology, ISBN 978-1-61353-176-1
5. RTCA DO 160, DO 178 standards

6. Model-Based Testing of Reactive Systems, Editors: Manfred Broy, Bengt Jonsson, Joost-Pieter Katoen, Martin Leucker, Alexander Pretschner, Springer, 2005

Course Code & Title
ISE 607 - Human Factors in Systems Engineering
Course Context
This course serves students in advanced students in human factors and human systems integration. The course enables students to understand the roles and risks of human factors in the design, operation, and modernization of complex systems. Behavioral and cognitive limitations of human operators and maintainers in complex systems play key roles in the overall performance, safety, and cost of operations. It is important that system architects, designers, engineers, and managers fully appreciation the information reception, information processing, and skilled performance issues involved. Emphasis is placed on methods, models, and techniques, including psychophysics, cognitive evaluations, field assessments, and surveys.
Course Objectives
1. Understand human factors and implications on system design 2. Understand human machine interactions 3. Apply various analysis techniques pertaining to human factors to be addressed in system design
Course Content
Unit I: Introduction to Human Factors: Human Factors Fundamentals, Role of Standards in Human Factors Unit II: Cognitive and Perceptual Processes: Sensation and Perception, Selection and Control of Action, Information Processing, Mental Workload Unit III: Design Principles and Ergonomics: Cross-Cultural Design, Anthropometry, Biomechanics, Task Analysis and Design, Situational Awareness Unit IV: Workplace and Environmental Design: Workplace Design Principles, Sound and Noise Factors, Occupational Health and Safety, Human Error and Reliability, Maintainability

Unit V: Modeling Human Performance:

Persona Development, Modeling Human Performance in Complex Systems, Virtual Environments, Neuro ergonomics

Unit VI: Human-Computer Interaction (HCI):

Human-Computer Interaction Principles, Usability Testing, Website Design Evaluation, Smarter Products and Technology Integration

Unit VII: Design Approaches:

Cross-Cultural Issues in Design, Universal Design Principles, Empathy and Affinity in Design, User-Centered Design of Consumer Products

Unit VIII: Practical Applications and Case Studies:

Case Studies in Human Factors and Design, Group Projects on Human Factors Applications

Course Outcome

CO1: Describe the role of standards and fundamentals of human factors in systems engineering

CO2: Describe the various design principles

CO3: Apply the humans factor engineering in the system of interest

CO4: Analyze a design and optimize for a system of interest

Text Books

1. "Handbook Of Human Factors And Ergonomic", by Gavriel Salvendy (Ed)., John Wiley & Sons, 2012.

Reference Books

1. "Engineering Psychology & Human Performance" by Wickens, Hollands, Parasuraman, & Banbury, 4th Ed., 2012.
2. "Human Factors & Ergonomics in Consumer Product design" by Waldemar Karwowski, Marcelo M Soares, Neville A Stanton, Crc press, 2011.

Course Code & Title
ISE 608 - System Safety & Reliability
Course Context
System safety analysis builds upon the fundamentals of good systems thinking, analyzing each requirement from macro to micro level behavior and eliminate or control safety risk potential. Safety risk potential pertains to any damage to the system, harm to the humans involved or damage to environment. Various analysis includes system safety analysis, functional hazard analysis and Fault Tree analysis. System reliability analysis is required to prevent or to reduce the likelihood or frequency of system failures. Analyzing the reliability of designs and addressing causes of failures is critical.
Course Objectives
1. Understand the fundamentals of reliability and safety management of safety critical systems. 2. Understand the use of core techniques and be able to apply these techniques to the analysis and design of safety critical systems. 3. Plan a reliability and safety management program for the acquisition or modification of a complex system. 4. Develop and critically review key reliability and safety program artefacts including management plans, analyses and arguments.
Course Content
Unit I: Introduction to System Safety: Introduction to System Safety, System Safety Planning, Safety Process Overview. Unit II: Hazard Identification and Analysis: Hazard Identification Techniques, Safety-Guided Design Principles, Hazard Risk Assessment, Risk Reduction Strategies, Hazard Control Measures. Unit III: STPA (System-Theoretic Process Analysis): Hazards and Losses, Hierarchical Control Structure, Unsafe Control Actions, Analysis. Unit IV: Safety Management Practices:

Safety Reviews and Audits, Hazard Tracking Mechanisms, Analysing Accidents and Incidents, Anomaly Reporting and Safety Practices, Building a Safety Culture

Unit V: Safety Standards and Guidelines:

Overview of ARP 4761, Safety Frameworks and Compliance.

Unit VI: Reliability Theory:

Introduction to Reliability Theory, Reliability Failure Models.

Unit VII: Quantitative System Analysis:

Quantitative Analysis Techniques, FMECA (Failure Mode, Effects, and Criticality Analysis), FTA (Fault Tree Analysis), RBD (Reliability Block Diagram), Markov Processes in Reliability Analysis, Reliability of Safety Systems

Unit VIII: Advanced Reliability Analysis:

Life Data Analysis Techniques, Bayesian Reliability Analysis

Course Outcome

CO1: Describe the different methods of safety analysis

CO2: Compute the FTA, RBD for a system of interest

CO3: Apply the principles of STPA for a system of interest

CO4: Analyze the architecture alternatives for system safety

CO5: Estimate the probability of failures for system of interest.

Text Books

1. "Reliability of Safety-Critical Systems: Theory and Application", Marvin Rausand, Wiley 2014

Reference Books / Materials

1. "System Safety Skeptic" by Terry L Hardy., AuthorHouse 2010
2. "Engineering a Safer World: Systems Thinking Applied to Safety" by Nancy G. Leveson, MIT Press, 2012.
3. "Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment is an Aerospace Recommended Practice from SAE", ARP4761.

4. "System Reliability Theory: Models, Statistical Methods & Applications", Marvin Rausand and Arnljot Hoyland,., John Wiley & Sons, 2004
5. STPA handbook

Course Code & Title
ISE 609 - Systems Life Cycle Cost Analysis & Risk Management
Course Context
Understanding the system scope of work and related cost is fundamental knowledge required to start any activity. Inadequate cost estimation and poor risk management are the leading causes of failure in development of engineered systems. This course covers different methods used to identify and measure the cost elements as the first step to build a cost estimate. The course also addresses methods to identify, analyze, treat and monitor risks. Numerous standards and guidelines As part of this course, there is an opportunity to apply the learnings in a case project using the concepts learned in class.
Course Objectives
1. Articulate basic concepts of cost estimation, different types of costs and their differences, 2. Proficiency in different methods used to estimate costs, how to gather information, compile and use a cost estimate, how to work with others, critique an estimate and provide insight on how to prepare one, 3. Familiarity with use of statistics and modeling techniques to improve the estimate. 4. Understand how to quantify risks, including risk levels , and assessing their impact on life cycle costs, schedule and performance
Course Content
Unit I: Introduction to Cost Estimation: Basic Concepts of Cost Estimation, Different Types of Costs and Their Differences, Importance of Credible, Supportable, Usable, Accurate, Achievable, Competitive, Complete, and Realistic Cost Estimates. Unit II: Cost Estimation Methods and Techniques: Methods Used to Estimate Costs, How to Gather Information, Compile, and Use a Cost Estimate, Working with Others: Critiquing an Estimate and Providing Insights, Use of Statistics and Modeling Techniques to Improve Estimates. Unit III: Project Management and Cost Estimation: Basic Project Management Techniques and Their Relationship to Cost Estimation, Cost Distribution Over the Life of a Project, Project Phases and Associated Costs and Risks, Unit IV: Decision-Making Tools for Cost Reduction:

Unit V: Risk Quantification and Analysis:

Quantifying Risks, Including Risk Levels, Assessing Impact on Life Cycle Costs, Schedule, and Performance, Basic Principles of Probability & Uncertainty and Their Implications in Risk Analysis, Correlation Among Risks

Unit VI: Data Gathering and Statistical Techniques:

Data Gathering Techniques for Cost Components and Risk Levels, Data Analysis and Statistical Techniques for Estimating Costs

Unit VII: Using Risk Analysis for Decision Making:

Using Risk Analysis to Support Decision Making

Course Outcome

CO1: Describe the concepts of risk management and cost estimation

CO2: Describe the statistical techniques of risk management

CO3: Apply the concepts to the system of interest

CO4: Develop a project plan to develop the system of interest.

CO5: Develop a risk management plan for the system of interest

Text Books

1. "Cost Estimating", by Steward, Rodney D., Second Edition, John Wiley and Sons
2. "Probability Methods for Cost Uncertainty Analysis: A Systems Engineering Perspective", by Garvey, Paul R, Marcel Dekker, Inc. 2000

Reference Books / Materials

1. "Foundations of Risk Analysis: A knowledge and Decision –Oriented Perspective" by Aven, Terji., John Wiley and Sons, Inc. 2008
2. "Hazop and Hazan: Identifying and Assessing Process Industry Hazards", by Trevor A Kletz

Course Code & Title
ISE 610 - AI-ML for Systems Engineering
Course Context
This course explores the integration of Artificial Intelligence (AI) and Machine Learning (ML) in systems engineering. It focuses on the application of AI and ML algorithms in system development, the use of open-source models and large language models (LLMs), and the process of developing AI systems for engineering applications. The course also covers AI tools used for system design, development, and certification, providing students with hands-on experience in utilizing these technologies within systems engineering frameworks
Course Objectives
1. Familiarize with fundamentals of AI & ML for Systems Engineering 2. Understanding different AI/ML algorithms and models 3. Learning AI tools and Techniques for System Developments 4. Understanding AI Ethics, Risk and Challenges
Course Content
Unit I: Fundamentals of AI and ML in Systems Engineering • Introduction to AI and Systems Engineering • Basic Concepts in Machine Learning • Mathematical Foundations for ML Unit II: AI/ML Learning Algorithms and Models • Supervised Learning Algorithms • Unsupervised Learning Algorithms • Deep Learning Models • Reinforcement Learning Unit III: Open Source Models and Large Language Models (LLMs) • Introduction to Open Source AI Models • Working with Large Language Models (LLMs) • Model Deployment Unit IV: AI Tools and Techniques for System Development • AI Tools in Systems Engineering • Developing AI Solutions for Systems Engineering • Lifecycle and Certification of AI Systems

Unit V: System Engineering for AI • AI System Design Process • AI Ethics, Risks, and Challenges • Project and Case Studies
Course Outcome
CO1: Understand the fundamentals of AI and Machine Learning and how they can be applied to systems engineering problems. CO2: Implement key AI/ML algorithms and models, and integrate them into engineering systems using open-source tools. CO3: Design AI-based solutions for complex engineering systems, applying system engineering principles to AI system development. CO4: Apply AI tools in system development, focusing on the development process, lifecycle, and certification of AI-based systems. CO5: Evaluate the ethical, regulatory, and technical considerations of deploying AI systems in real-world engineering environments.
Text Books
1. “Systems Engineering and Artificial Intelligence” by William F. Lawless, Ranjeev Mittu, Donald A. Sofge, Thomas Shortell, Thomas A. McDermott, , Springer
Reference Books / Materials
1. “Artificial Intelligence: A Modern Approach” by Russell/Norvig, 2. “Co-Intelligence: Living and Working with AI” by Ethan Mollick,

Course Code & Title
ISE 611 - Spacecraft Systems Engineering
Course Context
This course typically covers the design, development, and operation of spacecraft, including satellites, probes, and crewed vehicles. It integrates multiple engineering disciplines to ensure the successful performance of a spacecraft in its intended mission.
Course Objectives
1. Understand the fundamental concepts of spacecraft design and engineering. 2. Study the space environment, including vacuum, radiation, micrometeoroids, and thermal effects. 3. Learn about key spacecraft subsystems 4. Study orbit Dynamics and mission analysis, space craft propulsion, space craft power systems, communication
Course Content
Unit I: Spacecraft Systems Engineering Introduction to Spacecraft Systems Engineering; Anatomy of a Spacecraft; Types of Spacecraft Unit II: Space Environment and Its Effects on Spacecraft Design Launch Environment; Solar Influence on Space Environments; Radiation and Plasma Environments; Space Particulate Environment; Materials Selection and Effects Unit III: Orbit Dynamics and Mission Analysis Orbit Selection; Keplerian Dynamics; Orbital Perturbations Unit IV: Spacecraft Propulsion Launch Vehicles and Propulsion; Electric Propulsion; Secondary Propulsion Systems; Propellant Management Unit V: Spacecraft Power and Communications Spacecraft Power Systems; Thermal Control Systems; Communication Systems; On-board Data Handling
Course Outcome
CO1: Understand the Space Environment: Demonstrate knowledge of the space environment, including solar radiation, high-energy and low-energy plasma, space debris, and the effects of these environments on spacecraft design and materials.

CO2: Apply Orbital Mechanics: Utilize Keplerian dynamics, co-planar and non-planar orbital transfers, and perturbation analysis to perform orbital maneuvers for various mission types.

CO3: Design Spacecraft Propulsion Systems: Identify and evaluate the appropriate propulsion system (chemical, electric, or secondary) based on mission requirements and spacecraft needs.

CO4: Analyze Spacecraft Power Systems: Design spacecraft power systems, including solar arrays, batteries, RTGs, and fuel cells, while considering power distribution, regulation, and environmental factors.

CO5: Develop Thermal and Communications Systems: Understand and design thermal control systems for spacecraft and develop communication strategies, including TT&C and payload data transmission.

CO6: Perform Mission Analysis and Design: Apply spacecraft systems engineering principles to design and analyze space missions, considering cost, risk, and programmatic, and integrate spacecraft subsystems effectively.

Text Books

1. "Spacecraft Systems Engineering" by Fortescue, Swinerd & Stark (Editors) (2011). (4th Edition). John Wiley & Sons.

Reference Books / Materials

1. "Space Vehicle Design", Second Edition (AIAA Education) by Michael D. Griffin, James R. French
2. "Elements of Spacecraft Design" (AIAA Education) by Charles D. Brown
3. "Spacecraft Systems Engineering" 3rd Edition by Peter Fortescue (Editor), John Stark (Editor), Graham Swinerd (Editor)
4. "Space Mission Engineering: The New SMAD" (Space Technology Library, Vol. 28) Edited by James R. Wertz, David F. Everett, and Jeffrey J. Puschell
5. "Basics of Spaceflight" by Dave Doody, Jet Propulsion Laboratory
6. "The Space Environment and Its Effects on Space Systems" (AIAA Education Series) by Vincent L. Piscane
7. "Space Modeling and Simulation: Roles and Applications Throughout The System Life Cycle" by Larry B. Rainey
8. "The Space Environment: Implications for Spacecraft Design" by Alan C. Tribble

Course Code & Title
ISE 612 - Aircraft Systems Engineering
Course Context
This course typically covers the design, integration, and operation of various aircraft systems. It is a multidisciplinary subject that combines aerospace engineering, mechanical engineering, electrical engineering, and control systems.
Course Objectives
Understanding 1. Aircraft Systems & Subsystems 2. Systems Engineering Approach 3. Flight Control & Avionics 4. Propulsion & Power Systems 5. Safety, Reliability & Maintenance
Course Content
Unit I: Introduction to Aircraft Systems Engineering Overview of Aircraft Systems Engineering; Key Aircraft Subsystems; Systems Engineering Process Unit II: Aircraft Flight Control Systems Introduction to Flight Control; Control System Design; Human-Machine Interface (HMI); Autopilot and Flight Management Systems (FMS) Unit III: Aircraft Propulsion and Power Generation Systems Aircraft Propulsion Systems; Power Generation and Distribution; Fuel Systems Unit IV: Avionics and Onboard Communication Systems Avionics Systems; Communication and Data Networks; Flight Data Monitoring and Control Unit V: Aircraft Systems Integration, Testing, and Validation Systems Integration; Testing of Aircraft Systems; Safety, Reliability, and Redundancy
Course Outcome
CO1: Apply Systems Engineering Principles: Demonstrate the ability to apply systems engineering principles to design, integrate, and test aircraft flight control systems and other subsystems.

CO2: Design Flight Control Systems: Design and optimize aircraft flight control systems, considering stability, control, and human-machine interface.

CO3: Understand Propulsion and Power Generation: Understand the components and principles of aircraft propulsion systems, power generation, and their integration into the overall aircraft systems architecture.

CO4: Analyze Avionics and Communication Systems: Gain knowledge of avionics systems, onboard communication, and flight data monitoring, and their critical role in the operation of an aircraft.

CO5: Perform Aircraft Systems Integration and Testing: Understand the importance of system integration and testing in the development of aircraft systems and the methods used to ensure performance, safety, and reliability.

Text Books

1. "Aircraft Design: A Systems Engineering Approach" by Mohammad H. Sadraey,

Reference Books / Materials

1. "Aircraft Systems Mechanical, electrical, and avionics subsystems integration" by Ian Moir, Allan Seabridge,
2. "Systems Engineering for Aerospace A Practical Approach" by Richard Sheng,

Course Code & Title

ISE 613 - Automotive Systems Engineering

Course Context

This course typically covers the design, development, and integration of complex automotive systems, focusing on modern vehicle technologies. It blends mechanical, electrical, and software engineering principles to address real-world automotive challenges.

Course Objectives

1. Understand the principles of automotive systems and their interdependencies.
2. Study the architecture and design of major vehicle components (engine, transmission, braking, steering, suspension, etc.).
3. Analyze interactions between mechanical, electrical, and software components.
4. Understand the vehicle safety, testing and validation, quality assurance & certification.

Course Content

Unit I: Introduction to Automotive Systems Engineering

Overview of Automotive Systems Engineering; Systems Engineering Process in Automotive Design; Automotive Industry Standards

Unit II: Powertrain Systems and Integration

Powertrain Fundamentals; Transmission Systems; Hybrid and Electric Vehicle Powertrains; Powertrain Control Systems

Unit III: Chassis and Suspension Systems

Chassis Systems; Suspension Systems; Steering Systems; Braking Systems

Unit IV: Vehicle Electronics and Control Systems

Electrical and Electronics Systems; Control Systems and ECUs; Advanced Driver Assistance Systems (ADAS); Vehicle-to-Everything (V2X) Communication

Unit V: Automotive Safety, Testing, and Quality Assurance

Vehicle Safety Systems; Testing and Validation of Automotive Systems; Quality Assurance in Automotive Design; Vehicle Certification and Regulatory Compliance

Course Outcome

CO1: Apply Systems Engineering Principles to Automotive Design: Understand and apply the systems engineering approach to the design, integration, and validation of automotive systems, ensuring effective problem-solving and decision-making throughout the vehicle lifecycle.

CO2: Design and Integrate Powertrain Systems: Gain a comprehensive understanding of automotive powertrain systems, including internal combustion engines, electric propulsion, hybrid architectures, and transmission systems, and their integration into the vehicle.

CO3: Analyze and Optimize Chassis and Suspension Systems: Demonstrate knowledge of vehicle chassis design, suspension dynamics, and steering systems, and apply this knowledge to enhance vehicle performance, safety, and comfort.

CO4: Design and Implement Advanced Control and Electrical Systems: Understand and develop the electronic and control systems used in modern vehicles, including ECUs, sensors, actuators, and ADAS technologies, as well as their integration with vehicle subsystems.

CO5: Ensure Automotive Safety and Regulatory Compliance: Assess and implement vehicle safety features, including crashworthiness and active safety systems, and understand the testing, validation, and regulatory processes required to meet automotive industry standards.

Text Books

1. "Automotive Systems Engineering" by Markus Maurer (Editor), Hermann Winner,

Reference Books / Materials

1. “Automotive Technology: A Systems Approach” by Jack Erjavec
2. “Automotive Systems and Software Engineering: State of the Art and Future Trends” by Yanja Dajsuren (Editor), Mark Van
3. “Automotive Systems Principles and Practice” by Den Brand (Editor) G.K. Awari, V.S. Kumbhar, R.B. Tirpude,

Course Code & Title
ISE 614 - Medical Systems Engineering
Course Context
Health Care Systems Engineering (HCSE) integrates engineering principles with healthcare practices to optimize processes, enhance patient care, and improve operational efficiency within healthcare systems. This multidisciplinary field combines aspects of industrial engineering, systems analysis, and healthcare management to address complex challenges in the medical sector.
Course Objectives
1. Systems Thinking in Healthcare 2. Modeling and Simulation 3. Quality Improvement and Process Engineering 4. Healthcare Operations and Resource Management
Course Content
Unit I: Introduction to Healthcare Systems and Delivery Understanding Healthcare Systems; Systems Thinking in Healthcare; Healthcare Reform and Engineering Solutions Unit II: Quantitative Models and Healthcare Operations Statistical and Quantitative Models in Healthcare; Process Management and Optimization; Resource Allocation and Scheduling Unit III: Medical Automation Systems Principles of Medical Process Automation; System Design and Integration for Automation; Emerging Technologies in Medical Automation Unit IV: Telemedicine and Remote Patient Monitoring Telemedicine Technologies; Automated Patient Monitoring; Challenges and Opportunities in Remote Healthcare Unit V: Healthcare Systems Design, Integration, and Quality Control Healthcare Systems Design and Integration; Quality Control and Assurance in Healthcare;

Course Outcome

CO1: Apply Systems Engineering Principles to Healthcare: Understand and apply systems engineering principles and processes to improve the design, delivery, and management of healthcare services.

CO2: Use Quantitative Models for Healthcare Optimization: Utilize statistical and quantitative models to optimize healthcare operations, including resource allocation, scheduling, and process management.

CO3: Design and Implement Medical Automation Systems: Design, integrate, and optimize medical automation systems, with a focus on improving efficiency, reducing costs, and minimizing errors in medical processes.

CO4: Leverage Telemedicine and Remote Monitoring: Understand the technologies and methodologies behind telemedicine and remote patient monitoring, and apply them to modern healthcare delivery systems.

CO5: Evaluate and Improve Healthcare System Performance: Implement quality control, continuous improvement strategies, and performance evaluation methods to enhance healthcare system efficiency, safety, and overall patient care outcomes.

Text Books

1. **“Healthcare Systems Engineering”**, by Paul M. Griffin, H B Nembhard, C J DeFlitch, N D Bastian, H Kang and D A Munoz

Reference Books / Materials

1. **“Health Care Operations Management: A Systems Perspective”**, by James R. Langabeer and Jeffrey Helton
2. **“Systems Engineering Approach to Medical Automation”**, by Robin Felder, Majd Alwan and Mingjun Zhang

Course Code & Title
ISE 615 - Software Systems Engineering
Course Context
Software Systems Engineering is a specialized field within systems engineering that focuses on the development of complex, software-intensive systems. It encompasses the analysis, design, development, testing, and maintenance of software, ensuring that these systems meet specific user needs while adhering to constraints such as quality, time, and budget.
Course Objectives
1. Understanding Software Development Phases 2. Applying Software Process Models 3. Gaining Knowledge in Software Engineering Methodologies 4. Emphasizing Quality Assurance 5. Developing Teamwork and Communication Skills 6. Preparing for Professional Practice
Course Content
Unit I: Foundations of Systems and Software Engineering Introduction to Systems Engineering and Software Engineering; Characteristics of Systems and Software-Enabled Systems; Distinctions between Physical Systems Engineers (PhSEs) and Software Systems Engineers (SwSEs); Overview of System Life Cycles and Engineering Disciplines Unit II: Development Approaches and Process Models Traditional System Development Models (Linear, Vee, Incremental); Iterative Software Development Models; Integrated Incremental-Iterative System Development Model (I3); Aligning Systems and Software Development Processes Unit III: Requirements and Architecture Definition Business and Mission Analysis for Software-Enabled Systems; Stakeholder Identification and Requirements Elicitation; System Capabilities and Technical Feasibility Assessment; Model-Based System Architecture and Design Strategies Unit IV: Implementation, Verification, and Validation

System Implementation and Integration Strategies; Verification and Validation Techniques for Software and System Components; Managing Quality Attributes in Software-Enabled Systems; Case Studies: Real-World System Development Scenarios

Unit V: Technical Management and Leadership

Planning and Estimating Technical Work; Risk Assessment and Control in Systems Engineering; Organizing and Leading Systems and Software Teams; Metrics, Measurement, and Continuous Process Improvement

Course Outcome

CO1: Understand and apply fundamental principles of systems engineering and software engineering to software-enabled systems.

CO2: Analyze and resolve challenges that arise from differences in systems and software engineering methodologies.

CO3: Develop system capabilities using integrated incremental and iterative development approaches.

CO4: Utilize model-based system architectures to design and manage complex software-enabled systems.

CO5: Apply project management techniques to plan, estimate, and control technical work in system development.

Text Books

1. "Systems Engineering of Software-Enabled Systems " by Richard E. Fairley

Reference Books / Materials

1. "Software Engineering: A Practitioner's Approach" by Roger S. Pressman and Bruce R. Maxim
2. "Software Engineering: Theory and Practice" by Shari Lawrence Pfleeger and Joanne M. Atlee
3. "System Engineering Management" by Benjamin S. Blanchard and John E. Blyler
4. "The Art of Software Testing" by Glenford J. Myers

Course Code & Title
ISE 641 - Systems Engineering Lab - 1
Course Context
This course introduces students to MATLAB as a powerful computational tool for modeling, analysis, and simulation within the field of systems engineering.
Course Objectives
The course emphasizes the application of MATLAB to systems engineering problems.
Course Content
Basic Matlab Commands – Arrays manipulation, matrices, polynomials, curve fits Advanced Matlab – optimization, excel interface Basic Simulink – Second order system, simulation, logic gates, discrete system elements Systems Composer – Model examples Requirements Toolbox Verification and Validation Toolbox
Course Outcome
CO1: Model and analyze complex systems using MATLAB and Simulink. CO2: Implement numerical methods and optimization relevant to systems engineering. CO3: Define system behaviors using system composer and attach requirements to them. CO4: Fundamentals of verification and validation using tools

Course Code & Title
ISE 642 - Systems Engineering Lab - 2
Course Objectives
• Systematic Requirements Engineering • Functional decomposition into objects and processes • Model-Based Architecture Design and interfaces • Capture of temporal behaviours
Course Content
Capella – Basic of modelling • Architecture diagrams • Dataflows diagrams • Functional chains diagrams • Sequence diagrams • Tree diagrams • Mode and States diagrams • Classes and Interfaces diagrams OPCAT • Object Process Methodology modelling • Objects, Process, States • Relationships
Course Outcome
CO1: Ability to create and manage system models using its graphical tools. CO2: Structuring systems using Operational Analysis, System Analysis, Logical Architecture, and Physical Architecture layers. CO3: Creating clear, scalable, and maintainable models for complex systems. CO4: Linking requirements to system models for improved verification and validation.

Department of Mechanical Engineering

DEPARTMENT OF MECHANICAL ENGINEERING

About the Department: The Mechanical Engineering Department seeks to combine excellence in education and research with service to Defence. The goal of our academic programmes in mechanical engineering is to provide students with a balance of intellectual and practical experiences that enable them to address a variety of Defence needs. The Department is one of the largest departments.

The Department is known for research and projects in fluid dynamics, heat transfer, finite element methods, vibrations, experimental stress analysis, vehicle dynamics, combat vehicle technology, armaments, ballistics, marine engineering, and other areas. Experimental and computational facilities are being continuously upgraded. The Department has established, over the years, a close interaction with the DRDO laboratories and industry. It has carried out a large number of consultancy and sponsored research projects, which have been successfully completed. A number of sponsored research projects are ongoing.

The Department has carried out significant curriculum development work in Mechanical Engineering. Apart from the regular courses the department offers, on a continual basis, a wide variety of short-term intensive programmes for personnel from DRDO laboratories, Armed Forces and industrial establishments. User-oriented M. Tech programmes on Armament/Combat Vehicles and Marine Engineering has been formulated as per the needs of the Defence sector. The Programmes offers a wide choice of specializations, electives and research areas. The department has laboratories in Mechanical System Design and Analysis lab, Vibration lab, Fluid & Thermal Engg lab and Manufacturing and Precision Engg lab etc.

Vision of the Department:

“The Department endeavors to become Centre of Excellence in Armaments/Combat vehicles, Marine engineering, Mechanical Systems Design”

Mission of the Department:

To impart advanced training, update knowledge, and develop skillsets required for R&D, design, development, production, quality assurance, and inspection of efficient and economical equipment/systems of armament, combat vehicles, marine systems for DRDO and Defence Services, other industries and society in large.

Program Educational Objectives (PEO's):

PEO1: Provide basic and advanced technical knowledge to the students in the field of Armament and Combat Vehicles, Marine Engineering, Mechanical System Design.

PEO2: Students should be capable of undertaking R&D, inspection, testing and evaluation of equipment/systems of Combat vehicles, Armaments, Marine systems and other industries.

Program Outcomes (POs)

PO1: An ability to independently carry out research /investigation and development work to solve practical problems

PO2: An ability to write and present a substantial technical report/document

PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

Program Specific Outcomes (PSOs)

PSO1: The specific outcome of the program is to provide human resources equipped with advanced applied knowledge in the field of armaments & combat vehicle technology, marine engineering and mechanical system design to fulfill the needs of DRDO, Army, Navy and Defence PSU's and other industries thereby making the country self-reliance.

PSO2: To be able to apply advanced engineering principles and concepts to design of equipment/systems of armament & combat vehicles, marine and other industries within realistic constraints.

PSO3: To be able to design and device new procedures to arrive at a solution for design or troubleshooting problems at the system/component level.

M. Tech. in Mechanical Engineering [Marine]

Brief Description: The aim of the programme is to impart advanced training and to update knowledge in the field of marine systems like gas turbine, engines, tribology, warship transmissions and Diesel engines etc, to engineering officers from Indian Navy, Coast Guard, DRDO scientists, DPSUs and GATE qualified students. At the end of the programme the officer/student should be able to undertake R&D work and evaluation of Marine Engineering Equipment systems.

Eligibility: Bachelor's Degree in Mechanical/Marine/Naval Architecture and Ship Building/Ocean Engineering or Mechanical Allied departments (Aerospace, Automobile Engineering, Production Engineering, and Mechatronics) or in related Engineering field of an AICTE approved/recognized Institute/University.

Organization: M. Tech Mechanical Engineering with specialization Marine Engineering is a four-semester programme. In the first semester there are six courses. In the second semester, there are six courses. In each of these semesters, there will be three tests and a final semester examination of every course. In 3rd and 4th semester dissertation work is to be completed. Half yearly evaluation of the project takes place at the end of the third semester. At the end of the final semester, the student submits a thesis and makes a presentation about the project, which is evaluated by the Internal and External examiners.

Visits to various DRDO labs like NSTL, ARDE, GTRE, VRDE, Industry like MDL, GSL involved with Indian navy and naval technical facility are planned to enhance student's appreciation & understanding of the subject and provide them with opportunity to get hands on experience on various test equipment and procedures related to design, manufacturing and testing of Marine Engineering Equipments.

The details of the courses offered under the programme:

M. Tech. in Mechanical Engineering [Marine]

Semester-I

Sl. No.	Course Type	Course Code	Course	Contact Hours per week		Total Credits (*)
				L/T	P	
1	PSC-1	ME 602	Advanced Mechanics of Materials	3	0	3
2	PSC-2	ME 603	Advanced Fluid & Thermal Sciences	3	0	3
3	PSC-3	ME 609	Mechanical Vibrations	3	0	3
4	PSC-4	ME 641	Warship Transmission & Tribology	3	0	3
5	PE- 1	-	-	3	0	3
6	PSL/PE	ME 665L	Lab in Mechanical Engineering	0	6	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total	17	6	20

Semester-II

Sl. No.	Course Type	Course Code	Course	Contact Hours per week	

				L/T	P	Total Credits (*)
1	PSC-5	ME 644	Marine Diesel Engines	3	0	3
2	PSC-6	ME 645	Marine Gas Turbines	3	0	3
3	PE- 2	--	---	3	0	3
4	PE- 3	--	---	3	0	3
5	PE- 4	--	---	3	0	3
6	PE- 5	--	---	3	0	3
7	PGC	PGC-602	Professional Development & Employability Skills (PDES)	2	0	2
			Total	20	0	20

Semester - III

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 651	M.Tech. Dissertation Phase I	20		20
		Total	20		20

Semester - IV

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 652	M.Tech. Dissertation Phase II	20		20
		Total	20		20

* 1 credit in Theory/Tutorial means one contact hour per week and 1 credit in Practice/Project Thesis means two contact hours per week.

Nomenclature:

PSC: Program Specific Core

PSL: Program Specific Lab

PE : Professional Elective

PGC: Post Graduate Committee

List of Professional Electives (I)

Sr. No.	Course Code	Course Title
1	ME 643	Ship Dynamics & Marine Systems
2	ME 664	Advanced Thermodynamics

List of Professional Electives (II, III, IV & V)

Sl. No.	Course Code	Course Name
1.	ME 607	Computational Fluid Dynamics
2.	ME 608	Finite Elements Methods
3.	ME 611	Design for Manufacturability
4.	ME 616	Thermal Management of Defence Equipment
5.	ME 618	Composite Structures
6.	ME 619	Tribology for Design
7.	ME 627	Fatigue & Fracture Mechanics
8.	ME 628	Design of Hydraulic and Pneumatic Systems
9.	ME 630	Design of Machinery
10.	ME 631	Product Design and Development
11.	ME 637	Design of Pressure Vessels
12.	ME 642	Automatic Control Systems
13.	ME 646	Nuclear Reactor Engg.
14.	ME 654	Convective Heat Transfer
15.	ME 657	Marine Hydrodynamics
16.	ME 660	Heat Exchanger Design
17.	ME 661	Computational Fluid-Structure Interaction and its Applications
		Open Electives or any course from other departments

Notes:

1. The department has to decide which subjects should be offered as **Professional Elective I, II, III and IV.**
2. Practice school (Optional) of 4 weeks duration during Summer Vacation.

M. Tech. in Mechanical Engineering [Mechanical System Design]

Brief Description: M. Tech. in Mechanical Engineering (Mechanical System Design) plays a vital role in the field of Mechanical Engineering discipline from the fundamentals to applications in industrial/Defence practices. The importance of this program is vivid from understanding basics, design, development and implementation of mechanical systems.

The objective of the entire program is to impart knowledge to Engineers/ Scientists pertaining to Mechanical system design from the basics of engineering to final machine or equipment design ready to use in engineering systems. This can be achieved by teaching a candidate a different range of subjects for enhancing their analytical skills related to Machine design. Another objective of the program is to produce quality design engineers to cater to the needs of the relevant industry. The programme is conducted by well-versed faculty, and invited experts from reputed institutions and industries.

Eligibility:

1. B.E/B. Tech or equivalent in any stream of Engineering of a recognized Institute/University.
2. This programme is open for civilian GATE qualified candidates, DRDO Scientists/Officers and Officers from Tri-services. This programme is also open to foreign nationals from the countries approved by GOI.

Organization: M. Tech Mechanical Engineering with specialization in Mechanical System Design is a four-semester programme. In the first semester, there are six courses. The second semester consists of six courses. In each of these semesters, there will be three tests and a final semester examination for every course. In the third semester, M. Tech. (Phase-I) dissertation is there and in the fourth semester, Phase-II dissertation work is to be completed. Half yearly evaluation of the project takes place at the end of the third semester. At the end of the final semester, the student submits a thesis and makes a presentation about the M. Tech. project, which is evaluated by the Internal and External examiners. The details of the courses offered are:

The details of the courses offered under the programme:

M. Tech. in Mechanical Engineering [Mechanical System Design]

Semester-I

Sl. No.	Course Type	Course Code	Course	Contact Hours per week		Total Credits (*)
				L/T	P	
1	PSC-1	ME 602	Advanced Mechanics of Materials	3	0	3
2	PSC-2	ME 603	Advanced Fluid & Thermal Sciences	3	0	3
3	PSC-3	ME 604	Advanced Defence Materials and Processing	3	0	3
4	PSC-4	ME 609	Mechanical Vibrations	3	0	3
5	PE-1	-----	-----	3	0	3
6	PSL	ME 665L	Lab in Mechanical Engineering	0	6	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total	17	6	20

Semester-II

Sl. No.	Course Type	Course Code	Course	Contact Hours per week	

				L/T	P	Total Credits (*)
1	PSC-5	ME 630	Design of Machinery	3	0	3
2	PSC-6	ME 631	Product Design and Development	3	0	3
3	PE-2	--	-----	3	0	3
4	PE-3	--	-----	3	0	3
5	PE-4	--	-----	3	0	3
6	PE-5	--	-----	3	0	3
7	PGC	PGC-602	Professional Development & Employability Skills (PDES)	2	0	2
			Total	20	0	20

Semester-III

Sl. No.	Course Code	Course	Contact Hours per week		Total Credits (*)
			L	T/P	
1	ME 651	M.Tech. Dissertation Phase- I	40		20
		Total	40		20

Semester-IV

Sl. No.	Course Code	Course	Contact Hours per week		Total Credits (*)
			L	T/P	
1	ME 652	M.Tech. Dissertation Phase- II	40		20
		Total	40		20

* 1 credit in Theory/Tutorial means one contact hour per week and 1 credit in Practice/Project Thesis means two contact hours per week.

Nomenclature:

PSC: Program Specific Core

PSL: Program Specific Lab

PE : Professional Elective

PGC: Post Graduate Committee

List of Professional Elective-1

Sr. No.	Course Code	Course Title
1	ME 618	Composite Structures
2	ME 619	Tribology for Design

List of Professional Elective -2 & 3

Sr. No.	Course Code	Course Title
1	ME 608	Finite Elements Methods
2	ME 627	Fatigue and Fracture Mechanics
3	ME 628	Design of Hydraulic and Pneumatic Systems

List of Professional Elective - 4 & 5

Sr. No.	Course Code	Course Title
1	ME 607	Computational Fluid Dynamics
2	ME 611	Design for Manufacturability
3	ME 616	Thermal Management of Defence Equipment
4	ME 617	Kinematics and Dynamics of Machinery
5	ME 634	Experimental Stress Analysis
6	ME 636	MEMS: Design, Fabrication and Characterization
7	ME 637	Design of Pressure Vessels
8	ME 654	Convective Heat Transfer
10	ME 660	Heat Exchanger Design
11	ME 661	Computational Fluid-Structure Interaction and its Applications
		Open Electives or any course from other departments

M. Tech. in Mechanical Engineering [Armament and Combat Vehicles]

Brief Description: DRDO has been involved in the design and development of efficient and economical Combat Engineering & Armament Systems for Indian Armed Forces. The programme is designed to provide students with the principles of Combat Vehicle Technology and Armament Engineering. The programme pays special attention to:

- The study of advances in combat vehicle technology and armament engineering.
- Developing skills in the analysis and evaluation of new concepts against changes and developments in the threat.
- The user requirements needed to meet the threat and its implications.

Eligibility:

The eligibility for the postgraduate programme will be Bachelor's degree (B.E./ B. Tech.) in Engineering disciplines from a recognized university. This programme is open for civilian candidates, DRDO Scientists/Officers, Officers from Tri-services, Executives from Defence PSU's and Private Defence Industries. This programme is also open to foreign nationals from the countries approved by GOI.

Organization: M. Tech. Mechanical Engineering with specialisation in Armament and Combat Vehicles is a four-semester programme. In the first semester there are six courses, in second semester,

there are six courses. In each of these semesters, there will be three tests and a final semester examination for every course. In third semester M. Tech. (phase I) dissertation is there and in fourth semester, only dissertation work is to be completed. Half yearly evaluation of the project takes place at the end of the third semester. At the end of the final semester, student submits a thesis and makes a presentation about the M. Tech. project, which is evaluated by the Internal and External examiners.

Note: Students are encouraged to take an audit course during M.Tech. Dissertation Phase-I and II offered in 3rd and 4th semesters respectively.

The details of the courses offered under the programme:

M. Tech. in Mechanical Engineering [Armament and Combat Vehicles]

Semester I

Sl. No.	Course Code	Course	Contact Hours per week		Total Credits (*)
			L/T	P	
1	ME 601	Combat Vehicles Engineering and Technology	3	0	3
2	ME 602	Advanced Mechanics of Materials	3	0	3
3	ME 609	Mechanical Vibrations	3	0	3
4	ME 604	Advanced Defence Materials and Processing	3	0	3
5	ME 603	Advanced Fluid & Thermal Sciences	3	0	3
6	ME 662	Combat Vehicle Engineering Lab	0	6	3
7	PGC-601	Research Methodology and IPR	2	0	2
		Total	17	06	20

Semester II

Sl. No.	Course Code	Course	Contact Hours per week		Total Credits (*)
			L/T	P	
1	ME 610	Armament Engineering and Technology	3	0	3
2	ME 615	Trials & Evaluation of Weapon and Combat Systems	3	0	3
3	--	Department Elective-I	3	0	3
4	--	Department Elective-II	3	0	3
5	--	Elective-III	3	0	3
6	ME663	Armaments Engineering Lab	0	6	3
7	PGC-602	Professional Development & Employability Skills (PDES)	2	0	2
		Total	17	06	20

Semester III

		Course	Credits	

Sl. No.	Course Code		L	T/P	Total Credits (*)
1	ME 651	M.Tech. Dissertation Phase-I	20		20
		Total	20		20

Semester IV

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 652	M.Tech. Dissertation Phase-II	20		20
		Total	20		20

* 1 credit in Theory/Tutorial means one contact hour per week and 1 credit in Practice/Project Thesis means two contact hours per week.

PSL: Program Specific Lab

Sr. No.	Course Code	Course Title
1	ME 662	Combat Vehicle Engineering Lab
2	ME 663	Armaments Engineering Lab

List of Department Electives (I & II)

Sr. No.	Course Code	Course Title
1	ME 660	Heat Exchanger Design
2	ME 661	Computational Fluid-Structure Interaction and its Applications
3	ME 616	Thermal Management of Defence Equipment
4	ME 625	Combat Vehicle Technology
5	ME 607	Computational Fluid Dynamics (CFD)
6	ME 608	Finite Element Methods (FEM)
7	ME 611	Design for Manufacturability
8	ME 622	Ballistics
9	ME 624	Small arms and cannons
10	ME 623	Design of ordnance, basic structure and super structure
11	ME 621	Dynamics & Armament Mechanisms
12	ME 626	Vehicle Dynamics

List of Electives (III)

S. No.	Course Code	Course Title

1.	ME 612	Modeling and Simulation of Military vehicles
2.	ME 654	Convective Heat Transfer
3.	ME 614	Unmanned Ground Vehicles
4.	ME 615	Trials & Evaluation of Weapon Systems
5.	ME 617	Kinematics and Dynamics of Machinery
6.	ME 618	Composite Structures
7.	ME 619	Tribology for Design
8.	ME 620	High Energy Material Technology
9.	ME 627	Fatigue and Fracture Mechanics
10.	ME 628	Design of Hydraulic and Pneumatic Systems
11.	ME 630	Design of Machinery
12.	ME 642	Automatic Control System
		Open Electives

Notes:

1. The department has to decide which courses should be offered as Professional Elective PE-1,2 and 3 in the Semester -I and II.
2. Practice school (Optional) of 4 weeks duration during Summer Vacation.

Course Name- *Combat Vehicles Engineering and Technology*

Course Code- *ME 601*

Course Outcome (COs):

CO1 Understand the role of threat spectrum and battlefield environment in design of combat vehicles.

CO2 Understand the design and performance parameters of a combat vehicle.

CO3 Analyze the different components and their functions in connection with combat vehicle design and apply the understanding to the design of future systems

CO4 Understand and evaluate the requirement of different components as per futuristic combat vehicle design and propose solutions to the existing problems persisting in current inventory of combat vehicles.

Unit I: Threat Spectrum - Types of Conflicts - Low level, Medium level, Heavy conflicts - Combat Vehicle during World Wars I & II - Post world wars Combat Vehicles. Conventional threats - Tank threat, Mine threat, Missile threat; Non-conventional threats - Ariel threat - Aircrafts, Helicopters, Drones - Precision munitions delivered from various platforms - Nuclear threat - Conflicts in builtup areas - Close combat - peace keeping missions.

Unit II: Battle Field Environment - Firepower - Non lethal, low calibre, Heavy calibre (tank / Arty), Cannon launched Missiles; Mobility - Tactical, Strategic, Battle field Mobility - weight, transportability, logistics; Protection - Small arms, Splinters, KE attack, CE Attack, Passive and Active, camouflage and stealth; Command-Control-Communication-Computer-Intelligence (C4I) - Network Centric Warfare - Battlefield Management System - Situational awareness through sensors.

Unit III: Combat Vehicle design and Performance: Critical dimensions – NGP, MMP, Steerability ratio, Pitch ratio, Angle of approach, Angle of Departure, No. of Axles, No. of road

wheels, Buoyancy for Amphibious vehicles; Terramechanics - soil strength, bearing capacity, Tractive effort, rolling resistance, draw bar pull and slip. Vehicle stability, Modularity, Transportability to area of operation (by road, rail or by air), logistics for operation.

Unit IV: Power packs for Combat Vehicles: Power plants - Reciprocating engines, Military Specials, Component technology advances, Space consideration (packaging subsystems), supercharging turbo charging; Cooling and air filtration systems; Engine management systems; Gas turbines (Rotary Engine) - Types for Combat vehicle use, Air handling, Fuel management system; Wankel Engines - Sealing and Lubrication systems; Non-conventional power plants - Types of electric traction motors, onboard power generation, storage and distribution system; Introduction to Fuel cells.

Unit V: Transmission and Steering: Tractive requirement for wheeled and Tracked vehicles; Design of Clutches, Hydrokinetic and Hydro static Drives; Multi Axle all-wheel drive steering system for wheeled vehicles, Double differential steering for tracked vehicles, Skid steering for both wheeled and tracked vehicles; Electric / Hybrid transmission system; Brake system for combat vehicles.

Unit VI: Running gear: Suspension system requirement - Quarter car and Half car analysis for displacement and force transmissibility; Ride - pitch and bounce behavior and optimization using damping; Types - Coil Spring, Torsion bar, Hydro Gas, Active, semi-active; Terrain characteristics. Human response to vibration, Suspension system requirements, Ride and handling of vehicles, Passive suspension system, hydro-gas suspension. Pitch and bounce behavior, Suspension system transmissibility, Suspension system optimization, Introduction to semi-active and active suspension.

Text Books/References:

1. Tank Technology (Vol I & II) by RM Ogorkiewicz – Jane's information Group, 1991 – ISBN: 0710605951, 9780710605955.
2. TANKS: Main Battle and Light tanks (Brassey's Modern Military Equipment) , ISBN-13: 978-1857531688
3. Armoured Fighting Vehicles: Brassey's Modern Military Equipment, ISBN-13: 978-1857532036
4. **Military Ballistics (Brassey's New Battlefield Weapons Systems & Technology Series into the 21st Century), ISBN-13: 978-18575308415.** Theory of Ground Vehicles by J.Y.Wong – John Wiley & Sons, INC., 3rd Edition, ISBN: 0-471-35461-9

Course Name- *Advanced Mechanics of Materials*

Course Code- *ME 602*

Course Outcome (COs):

- CO1** Understand the fundamental concepts of stress and strain and the relationship between both through the strain-stress equations in order to solve problems for simple tri-dimensional elastic solids.
- CO2** Determine Stress/strain invariants, principal strains and their directions. Analyze theories of failure to design components for safe operation.

- CO3** Solve problems relating to non-uniform beams and thin-walled open section. Analyze the stresses in rotating discs, thick cylinder and bars subjected to torsion.
- CO4** Develop constitutive relationships between stress and strain for linearly elastic solid and apply the concepts of energy methods in solving structural problems.

Unit I: Theory of Elasticity-Introduction, Stress. Differential equations of equilibrium, strain, compatibility conditions, plane problems of elasticity, stress strain relations, stress functions and applications in 2D problems. Pressurized cylinders & rotating disks, Governing equations, Stresses in thick-walled cylinder under internal and external pressures. Introduction to experimental stress analysis (strain gauges), Theories of failure.

Unit II: Energy Methods-Work done by forces and strain energy, reciprocal relations, Castigliano's theorems, Fictitious load method, statically indeterminate structures, theorem of virtual work, generalization of Castigliano's theorem.

Unit III: Asymmetrical Bending of beams-Bending of prismatic bars and unsymmetrical bending. Concept of shear centre in symmetric and un-symmetric bending, Plate bending, bending of curved beams.

Unit IV: Torsion of non-circular sections-Introduction, torsion of general prismatic solid section like circular, elliptical, rectangular, triangular shafts, membrane analogy, torsion of thin walled tubes, torsion of thin walled multiple cell closed sections.

Text Books/References:

1. Theory of Elasticity, 1970, Timoshenko SN & Goodier JN, McGraw Hill.
2. Advanced Mechanics of Materials, 2nd Ed., 1998 Cook RD & Yound WC, Prentice Hall.
3. Advanced Mechanics of Materials, 5th Ed., 1995 Boresi AP, Sidebottom OM, John Wiley.
4. Experimental Stress Analysis, 3rd Ed., 2005, Dally JW & Riley WF, College House Enterprises.

Course Name- *Advanced Fluid & Thermal Sciences*

Course Code- *ME 603*

Course Outcomes (COs):

- CO1** Understand and review the basics of fluid mechanics.
- CO2** Understand the basic governing equations of fluid flow and heat transfer, Application of dimensional analysis in fluid flow and heat transfer problems.
- CO3** Application of governing equations in various processes, Problem solving skills of fluid flow and heat transfer.
- CO4** Understand the turbulent models for CFD, knowledge of compressible flow and heat transfer, Application of governing equations of fluid flow and heat transfer.

Unit I: Review of concepts in kinematics of Fluid Motion, Vorticity, Circulation, Velocity potential and Stream function. Reynolds transport theorem, Governing equations in integral form, Momentum Theorem, Applications in Propulsion, Energy equations, Applications.

Unit II: Potential flows, Applications, Integration of Euler's equations of motion. Governing Equations of fluid flow in differential form, Navier-Stokes Equations and exact solutions, **Couette Flow, Hagen Poiseuille Flow**, Energy Equation and solution of fluid flow with thermal effects.

Unit III: Dimensional Analysis. Prandtl's Boundary Layer equations, Laminar Boundary Layer over a Flat Plate, Blasius solution. Turbulent flows in two-dimensional channels and pipes, Velocity field, Smooth and Rough pipes, Drag reduction in pipes, Turbulent Boundary Layer over a Flat Plate, logarithmic Law of wall, Effect of Pressure gradient, Boundary Layer control.

Unit IV: Speed of sound and Mach number, Basic equations for one dimensional flow, Isentropic relations, Normal-shock wave, Rankine-Hugoniot relations, Fanno and Rayleigh curve, Mach waves, Oblique shock wave, Prandtl-Meyer expansion waves, Quasi-one-dimensional flows, Compressible viscous flows, Compressible boundary layers.

Unit V: Introduction to Heat Transfer.

Text:

1. "Introduction to Fluid Mechanics" by R.W. Fox and A.T. McDonald, McGraw Hill
2. "Fluid Mechanics" by Kundu & Cohen, Elsevier Publications
3. Heat Transfer by J P Holman and Souvik Bhattacharyya (10th Edition, McGraw Hill Education)

References:

1. Viscous Fluid Flow, 2005, F. M. White, McGraw-Hill.
2. Boundary Layer Theory, 8th ed, 2000, Hermann Schlichting, Springer

Course Name- *Advanced Defence Materials and Processing*

Course Code- *ME 604*

Course Outcomes (COs):

CO1 Understand the selection criteria and effect of alloying elements on material selection.

CO2 Selection of suitable materials for aerospace and defence applications.

CO3 CO3: Analyse and select appropriate machining process for defence materials.

CO4 CO4: Select a hybrid process for processing defence materials.

Course Contents:

Unit I: Introduction to metallic materials for military application, Effects of alloying elements on properties of materials, Requirement of complex metals and alloys for modern and sophisticated warfare weapons systems. Ultra-high-strength steel for defence applications. Rolled Homogeneous Armour steels and Tungsten heavy alloys (WHA)

Unit II: Aerospace Materials Properties and Processing: Materials required for engine parts, Super alloys for high temperature applications, Single crystal blades made of Ni based super alloys, Aerospace grade low density high strength Titanium alloys, Aluminium alloys and Magnesium alloys and shape memory alloys.

Unit III: Composite material for defence applications such as polymer matrix materials, Metal Matrix material, ceramic matrix materials, Titanium matrix materials etc. Fabrication and processing of composite materials. Structural Ceramic Armor Materials such as alumina, lead oxide, silicon nitride, silicon carbide, aluminum nitride, and its composite materials

Unit IV: Advanced processing techniques for defence materials such as deep drawing, flow forming, explosive forming, super plasticity. Powder metallurgy. High speed machining of defence materials, Advanced welding techniques, Advanced energy-based manufacturing processes such as Electrical discharge machining (EDM), Laser Beam Machining (LBM), Chemical machining, Electron beam machining (EBM)

Unit V: Introduction to Additive Manufacturing, Material selection for AM, Fused Deposition Modelling (FDM), Sheet Lamination AM Processes, Powder Bed Fusion AM Processes, Directed Energy Deposition AM Processes, Laser additive manufacturing (LAM), Post Processing of AM Parts, issues and challenges of AM and Wire Arc Additive Manufacturing (WAAM),

Text Books/References:

1. Gandhi, M.V. and Thompson, B.S., Smart materials and Structures, Chapman and Hall, 1992.
2. Otsuka, K. and Wayman, C. M., Shape memory materials, C.U.P, 1998
3. Taylor, W., Piezoelectricity, George Gordon and Breach Sc. Pub., 1985
4. Mallick, P.K., Fiber Reinforced Composites Materials, Manufacturing and Design Marcel Dekker Inc, New York, 1993.
5. William D Callister: Materials Science and Engineering: An Introduction, 6th Edition, Wiley Publication.
6. S. Kalpakjian and S. Schmid: Manufacturing Engineering and Technology, 4th Edition, Pearson Education.
7. M. P. Grover: Fundamentals of Modern Manufacturing: Materials, Processes & Systems , Prentice Hall.

Course Name- **Introduction to Combat Systems**

Course Code- **ME 605**

Course Outcome (COs):

- CO1** Understand the basics of the threat spectrum depending upon types of conflicts, types of conventional threats, close combat and peace keeping missions.
- CO2** Understand battle field environment in reference to firepower mobility and protection, Command-Control-Communication-Computer-Intelligence (C4I) - Network Centric Warfare - Battlefield Management System. Evaluate the battle field environment and apply constitutive equations for firepower and protection analysis and calculations related to C4I and analyze the combat vehicle behavior at macro level.
- CO3** Analyze different types of combat vehicle configurations and their role in connection with the battlefield requirements, man machine interface and apply the understanding to the design of future combat systems.
- CO4** Understand and evaluate the requirement of maintainability of a combat system and Combat Vehicle Evaluation Techniques with different types of trials required for futuristic combat vehicle design and finding solution to the existing problems in current inventory of combat vehicles.

Unit I: Threat Spectrum - Types of Conflicts - Low level, Medium level, Heavy conflicts - Combat Vehicle during World Wars I & II - Post world wars Combat Vehicles. Conventional threats - Tank threat, Mine threat, Missile threat; Non-conventional threats - Ariel threat - Aircrafts, Helicopters,

Drones - Precision munitions delivered from various platforms - Nuclear threat - Conflicts in builtup areas - Close combat - peace keeping missions.

Unit II: Battle Field Environment - Firepower - Non lethal, low calibre, Heavy calibre (tank /Arty), Cannon launched Missiles; Mobility - Tactical, Strategic, Battle field Mobility - weight, transportability, logistics; Protection - Small arms, Splinters, KE attack, CE Attack, Passive and Active, camouflage and stealth; Command-Control-Communication-Computer-Intelligence (C4I) - Network Centric Warfare - Battlefield Management System - Situational awareness through sensors.

Unit III: Vehicle Configuration - On Road and Off-Road vehicles; Soft skinned - logistics, strategic transport (special railway wagons and multi-axle road trailers), Medium Armoured (both wheeled and tracked) - Infantry Combat Vehicles (ICV), Missile / Mortar Carrier Vehicle, Artillery Vehicles, Armoured Repair and Recovery Vehicle (ARRV), Bridge Layer, Main Battle Tank (MBT).

Unit IV: Man Machine Interface - Human System Integration - Ergonomics - Environmental Control System - Packaging of systems.

Unit V: Maintainability - Design for maintenance - Maintenance Repair and Overhaul (MRO) - Modularity in design - Adaptability to different missions, Line Replaceable Units.

Unit VI: Combat Vehicle Evaluation Techniques - Automotive trials - Specialized test track for automotive trials; Weapon Trials - Special equipment for proving weapon, proving Ammunition and Proving Combat system as a whole; Different types of Trials - Development trials, User trials, Usage trials, Deployment trials.

Text Books/References:

- 1) Fighting vehicle, TW Terry, Brassey's, 1991
- 2) The Greenhill Armoured Fighting Vehicles Data Book - Ian Hogg – Greenhill books - ISBN: 1853673919, 978-1853673917
- 3) The Encyclopedias of Tanks and Armored Fighting Vehicles – Chris Foss, Will Fowler – Thunder Bay Press (CA) – ISBN: 1571458069, 978-1571458063
- 4) Tanks inside Out – Michael E. Haskew – ISBN: 1607101106, 978-1607101109 Modern Tanks & Armoured Fighting Vehicles by Simon Dunstan – The Crowood Press, 2005 ISBN:1840371900, 9781840371901.

Course Name- *Computational Fluid Dynamics (CFD)*

Course Code- *ME 607*

Course Outcome (COs):

- CO1** Understand and review of basics of fluid mechanics, turbulence models etc
- CO2** Understand the basic governing equations of fluid flow and heat transfer.
- CO3** Understand Finite Difference, Finite element and Finite Volume methods.
- CO4** Understand Grid generation, errors and uncertainties, Practical's on CFD software (FLUENT) for better understanding

Course Contents:

Unit I: Basic of Computational Fluid Dynamics. Governing Equations of fluid mechanics and heat transfer: Continuity, momentum and energy equations, physical boundary conditions, basic aspects of Discretization.

Unit II: Finite Difference, Finite element and Finite Volume formulation of steady/transient one-dimensional conduction equation, Finite Volume formulation of steady one-dimensional convection and

diffusion problems: CDS, Upwinding scheme, hybrid scheme, unsteady problems: explicit scheme and Implicit scheme, FV formulation of 3D conduction equation.

Unit III: Solution algorithms for pressure-velocity coupling in steady and unsteady flows. Discretization equations for two-dimensional convection and diffusion. Unsteady heat conduction, Unsteady Heat Conduction problems of Implicit and Explicit schemes.

Unit IV: Numerical methods for the Navier-Stokes equation. Turbulence, Turbulence models: mixing length model, one equation model, Two equation (k-epsilon) models, LES, DNS.

Unit V: Grid generation, errors and uncertainties, Practical's on CFD software (FLUENT).

Practice in Ansys Workbench:

1. Turbulent Flow in a 2D elbow. (Use water)
2. Laminar Flow in a 2D Pipe. (Use water)
3. Flow over an Airfoil. (Use air)
4. Laminar flow over a flat plate.
5. Flow through a pipe bend
6. Flow in multichannel

Text books:

1. An introduction to Computational Fluid Dynamics, 2nd edition, 2007, HK Versteeg & W Malalasekera, Pearson Education.
2. Computational Fluid Dynamics & Heat Transfer, 1984, Anderson, Dale A, John C Tanehill and Richard H Pletcher, McGraw Hill.

References:

1. Introduction to Computational Fluid Dynamics, 2005, Anil W Date, Cambridge University Press, NY, USA.
2. Numerical Heat Transfer and Fluid Flow, 1980, Patankar SV, Hemisphere, New York.

Course Name- *Finite Element Methods*

Course Code- *ME 608*

Course Outcome (COs):

- CO1** Understand the Prerequisites to Finite Element Methods, analyze the 1-D structural problems related to FEM and Introduction to Finite Elements in Engineering.
- CO2** Analyze the 1-D structural problems including Analysis of Trusses and beams. Develop the understanding of 2D stress analysis using CST.
- CO3** Analyze the Scalar field problems including 1-D and 2-D heat conduction problems. Analyze the 3-D problems using Tetrahedron element - Jacobian matrix - Stiffness matrix.
- CO4** Understand the FEM through Case Studies including Modeling & Simulation of structural and non-structural problems using ANSYS, ABAQUS manuals.

Course Contents:

Unit I: Prerequisites to FEM-Application of FEM, Strain- displacement relations, Stress-strain relations, Differential equations of equilibrium, Co-ordinates, basic element shapes, interpolation function, Minimum potential energy. Properties of stiffness matrix, treatment of boundary conditions, solution of system of equations, shape functions and characteristics.

Unit II: 1-D structural problems-Analysis of axial bar element - stiffness matrix, load vector, temperature effects, Quadratic shape function. **Analysis of Trusses**-Plane Truss elements,

Transformation matrix, stiffness matrix, load vector Analysis of Beams - Hermite shape functions – beam stiffness matrix - Load vector - Problems

Unit III: 2-D stress analysis using CST-Plane stress, Plane strain, Force terms, Stiffness matrix and load vector, boundary conditions. Axisymmetric body subjected to axisymmetric loading-Numerical problems, Isoparametric element - quadrilateral element, linear shape functions.

Unit IV: Scalar field problems-1-D Heat conduction through composite walls, fins of uniform cross section, 2-D heat conduction problems, Torsional problems.

Unit V: Dynamic Considerations-Dynamic equations - consistent mass matrix – Eigen values, Eigen vector, natural frequencies - mode shapes - modal analysis.**3-D problems**-Tetrahedron element - Jacobian matrix - Stiffness matrix, CAD softwares and its applications, Brief description to analysis of Plates & Shells.

Practice:

- (i) Stress Analysis of Plate with Cut-outs using ANSYS/ABAQUS Software
- (ii) Modal Analysis of Cantilever Beam using ANSYS/ABAQUS Software
- (iii) Case Studies etc.

Text Books/References:

1. Introduction to Finite Elements in Engineering, Tirupathi R. Chandrupatla and Ashok D. Belagundu, Pearson Education (Singapore) Pte Ltd, 2006.
2. An Introduction to Finite Element Methods, J.N. Reddy, Tata Mc Graw Hill, 2008.
3. A First Course in the Finite Element Method by Daryl L. Logan.
4. Concepts and Applications of Finite Element Analysis, Robert Cook, Wiley India, Pvt., Ltd., 4th Edition-2007.
5. An Introduction to Finite Element Methods, J.N. Reddy, Tata Mc Graw Hill, 2008.
6. Finite Element Procedures, K.J. Bathe, PHI Learning, 2009.
7. The Finite Element Methods in Engineering / SS Rao / Pergamon.

Course Name- *Mechanical Vibrations*

Course Code- *ME 609*

Course Outcomes (COs):

- CO1** Understand the basics of single degree of freedom (DOF) systems such as free and forced vibrations of damped and undamped systems, Simple harmonic excitation, steady state response, torsional vibrations.
- CO2** Understand vibration of systems with 2-DOF such as free and forced vibration of spring-mass-damper systems, torsional vibrations, modal analysis of undamped and damped systems.
- CO3** Analyze the vibration of multi-DOF and continuous systems including free and forced vibration of beams, flexibility and stiffness influence coefficients with understanding of numerical methods.
- CO4** Understand the experimental methods in vibration analysis with case studies including vehicle dynamics, fluid-structure interaction problems, vibration of suspension bridges.

Course Contents:

Unit I: Single Degree of Freedom Systems- Free and forced vibrations of damped and undamped systems; Simple harmonic excitation; steady state response; torsional vibrations.

Unit II: Vibration of Systems with Two Degrees of Freedom- Free and forced vibration of spring-mass-damper systems; torsional vibrations; modal analysis of undamped and damped systems;

numerical methods: Matrix iteration, Holzer's method, Dunkerley's lower and Rayleigh's upper bound approximations; Dynamic vibration absorbers

Unit III: Vibration of Multi-degree of Freedom and Continuous Systems: Vibrating string; Longitudinal and torsional vibration of rods; Free and forced vibration of beams; Properties of vibrating systems: Flexibility and stiffness influence coefficients; Reciprocity theorem; Eigenvalue analysis; Orthogonality of eigenvectors; Modal matrix

Unit IV: Experimental methods in vibration analysis: Vibration instruments: exciters, transducers, analysers, measurement devices: vibrometers, velocity meters and accelerometers; Signal analysis techniques: time domain analysis, frequency domain analysis, amplitude and power spectra, coherence, auto and cross correlations, amplitude and frequency modulations; Tests for free and forced vibrations

Unit V: Case studies (A) -Vehicle dynamics: introduction to nonlinear and random vibrations, vehicle subjected to random vibrations (for example an uneven road); Fluid-structure interaction problems: vibration of suspension bridges. **Case studies (B)** - Introduction to nonlinear and random vibrations, structures subjected to random vibrations, Noise control and acoustics.

Text Books:

1. Introductory Course on Theory and Practice of Mechanical Vibrations, J.S. Rao, K. Gupta, Revised second edition, New Age International Publishers
2. Theory of Vibration with Applications, William T. Thomson, Marie Dillon Dahleh, Pearson Low Price Edition.
3. Mechanical Vibrations, J.B.K. Das & P.L.S. Murthy, Sapna book house.

Reference Books:

1. Principles and Techniques of Vibrations, Leonard Meirovich, Prentice Hall Inc.
2. Engineering Vibration, DJ Inman, Prentice Hall International Inc.
3. Mechanical Vibration and Shock Measurements, J.T. Broch, Bruel and Kjae Publication.
4. Applications of Random Vibrations, N. C. Nigam, S. Narayanan, Narosa Publishers.

Course Name- Armament Engineering and Technology

Course Code- *ME 610*

Course Outcome:

- CO1** Understand the basics of Armament Systems and ballistics, learn fundamentals of Weapon System and its classification, Principles and Factors affecting Design of Weapon, Weapon mount, Projectile and Turret, Ammunition & Missile Feed Systems, Extraction and Ejection Systems. Learn fundamentals of Gun and Rocket; Internal, Intermediate, External and Terminal ballistics and factors affecting performance of the weapon.
- CO2** Understand about Gun and Rocket; Internal, Intermediate, External and Terminal ballistics and factors affecting performance of the weapon. Learn and understand about Warhead Mechanisms, Ammunition and Design aspects of various types of fuzes. Apply constitutive equations for Internal, Intermediate, External and Terminal ballistics and evaluate engineering constants and analyze combat vehicle behavior at macro level.
- CO3** Analyze the different components and their functions in connection with Weapon Sighting and Fire control system. Understand and analyze types of Sighting Systems and their roles along with fire control systems. Emerging trends and feature of sighting and fire control system.
- CO4** Understand the requirement of different components as per futuristic combat vehicle design and proposing solution to the existing problems persisting in current inventory of combat vehicles.

Unit I: Armament Systems: Weapon System classification, Characteristics and Operating, Principles (Large caliber & Small caliber, Rockets, Missiles & Directed Energy Weapons (DEW)); Introduction to Turret and Weapon System (TWS), Principles and Factors affecting Design of Weapon, Weapon mount, Projectile and Turret; Automatic Fire - Blowback, Recoil System, Gas Operation systems and externally driven; Subsystems - Ammunition & Missile Feed Systems, Trigger and Firing Systems, Extraction and Ejection Systems, Locking, Mechanical Safety and Muzzle Attachments.

Unit II: Introduction to ballistics: Gun and Rocket; Internal, Intermediate, External and Terminal ballistics; Factors affecting performance of the weapon.

Unit III: Warhead Mechanisms: Configuration and classification of Warhead; Kill mechanisms – Kinetic Energy (long rod, fragmentation), Chemical Energy (Blast, Shaped Charge– HEAT, HESH, Explosive dynamics.); Explosives used in warheads.

Unit IV: Ammunition: Charge systems BL and QF. Primers and explosive trains; Design aspects of various types of fuzes.

Unit V: Introduction to Weapon Sighting system

Types of Sighting Systems and their roles, Building Blocks, Night Vision Systems, Infrared Imaging, Elements of thermal imaging systems, Day vision systems-Charged Coupled Devices (CCD) and CMOS Vision Systems, Elements of Day Vision Camera, Laser systems-Laser range finders, Laser Guidance & Designator, safety issues, Line of Sight Stabilization, Interfaces Types of Displays, Emerging trends and feature of sighting System.

Unit VI: Introduction to Fire Control System

Different Configurations of Fire Control systems, Building Blocks of IFCS, Features and salient Specifications, Gunner's Main Sight (GMS)-Elements of GMS, Configurations of GMS, Automatic target tracker, Commander's Sight- Salient Features and configuration, Panorama generation and Auto queuing, Ballistic computation, Gun Control system and its types.

Text Books/References:

1. "Handbook of Infantry Weapons", Part – 1, RMCS, UK, 1987
2. D Allsop, L Popelinsky et al, "Brassy's Essential Guide to Military Small Arms: Design Principles and Operating Methods", Brassy's, UK, 1997
3. "Engineering Design Handbook: Automatic Weapons", AMC Pamphlet No. 706 – 260,
4. US Army Material Command, Washington, 1970
5. Military Ballistics: A Basic Manual (Brassy's New Battlefield Weapon System and Technology Series) 1999, CL Farrar, DW Leeming, GM Moss, Brassey's (UK) Ltd.
6. Surveillance and Target Acquisition Systems: Brassey's Land Warfare, 1997, MA Richardson, IC Luckraft and RF Powell, London:Brassey's, ISBN 978-1857531374
7. Richard M Lloyd, "Conventional Warhead Systems Physics and Engineering Design", Vol. 179, Progresses in Astronautics and Aeronautics, 1998
8. Guided Weapons: Including Light, Unguided Anti-Tank Weapons, 3rd edition, 1998, RG Lee, TK Garland Collins, CA Sparkes and E Archer, London: Brassey's, ISBN 978-1857531527
9. Richard M Lloyd, "Conventional Warhead Systems Physics and Engineering Design", Vol. 179, Progresses in Astronautics and Aeronautics, 1998
10. MYH Bangash, "Impact and Explosion Dynamics Analysis and Design", Blackwell Scientific Publications, 1993.

Course Name- *Design for Manufacturability*

Course Code- *ME 611*

Course Outcome (COs):

- CO1** Understand the Design for manufacture overview, GD&T, Processing techniques and limitations.
- CO2** Understand the Design for Manufacturing (DFM) and Fundamental principles of DFM.
- CO3** Understand the Design for Assembly (DFA) and Concurrent engineering approach.
- CO4** Analyze the Design Evaluation Tools/Softwares.

Course Contents:

Unit I: Manufacturing Considerations in Design- Design for manufacture, Tolerancing and tolerance analysis. Processing techniques and limitations for metals, polymers and ceramics. Influence of materials in processing and tooling on the design of components. Finishing, surface coatings and surface modifications of materials.

Unit II: Engineering Design- Design of cast, forged, sheet metal parts and welded constructions. Design for assembly and dismantling, modular constructions. Erection, operation, inspection and maintenance considerations, Ergonomics.

Unit III: Machining considerations- Design for accuracy, locating pins and registers, machining in assembly, adjustment. Backlash and clearance adjustment. Examples illustrating the various principles. Available design variants for some of the common basic functional requirements.

Text Books/References:

1. Ashby, M. F. “Materials Selection in Mechanical Design”, Pergaman Press, 1992.
2. Bralla J., “Handbook of Product Design for Manufacture”, McGraw Hill, 1988.
3. Levy S., and Dubois, L. H, “Plastics Production Design Engineering Handbook, Methuen Inc., 1985.
4. Dieter G E, Engineering Desing, McGraw-Hill, 1991.
5. YotaroHatamura, The Practice of Machine Design, Claredon Press Oxfor, 1999.
6. ErtasAtilia and Jones J C, The Engineering Design Process, John Wiley & Sons, 1996.
7. Waldron B M and Kenneth J W, Mechanical Design: Theory and Methodology, Springer, 1996.

Course Name- *Modeling and Simulation of Military Vehicles*

Course Code- *ME 612*

- 1. Introduction to Multi Body Dynamics.**
- 2. Vehicle dynamics evaluation using commercial software**
 - (i) LMS Virtual Lab (or)
 - (ii) ADAMS, ADAMS (ATV) (or)
 - (iii) Recurdyn
- 2(a). Modelling of Track**
 - Super Element Track Modelling
 - Discrete track modelling
- 2(b). Modelling of tyre**
- 2(c). Modelling of Terrain**
 - 3D Surface modelling

- Representation of soft terrains
- 2(d) Steering and motion controls
- 2(e) Co-simulation techniques
- 2(f) Modelling of contact elements
 - Contact between track and terrain
 - Contact between track and other turning gear elements
 - Contact between tyre and terrain
- 3. Introduction to Modal Analysis**
 - Virtual Experimental Modal Analysis (VEMA) using.
- 4. Structural analysis of hull and chassis**
 - Flexi body MBD modelling
- 5. Prediction of vehicle performance characteristics using vehicle dynamics model –**
 - Ride evaluation
 - Low speed, high speed handling
 - Obstacle crossing
 - Mobility evaluation
- 6. Introduction to CFD softwares.**
 - CFD analysis of hull/body for hydrodynamic performance of vehicles engaged in swimming, planning, steering and other manoeuvres.
- 7. Armour / Ballistics**
 - Introduction to softwares such as LS Dyna, Radios
 - Prediction for survivability of blast load or incoming projectile; penetration, or elastic and plastic deformation.
- 8. Experimental testing of vehicle and systems for validation of simulation models.**

Text Books/References:

1. Multibody Dynamics: Computational Methods & Applications, 2007, J.C.G.Orden, J.M.Goicolea & J.Cuadrado, Springer, ISBN 978-1402056833
2. Study of Vehicles Handling & Riding Characteristics by ADAMS Software, 2012, Wael-Al-Tabey, LAP Lambert Academics Publishing, ISBN 978-3848439423
3. Tyre and Vehicle Dynamics, 2nd edition, 2005, Hans B Pacejka, Butterworth Hienemann, ISBN 978-0750669184
4. Modal Analysis, Zhi-Fang Fu and Jimin He, 2001, Butterworth Hienemann, ISBN 978-0750650793
5. Motor Vehicle Structure: Concepts and Fundamentals, 2002, JC Brown, AJ Robertson and ST Serpento, SAE International, ISBN 978-076800909
6. Introduction to Hydrocodes, 2004, Jonas Zukas, Elsevier Science, ISBN 978-0080443485
7. LS-DYNA for Engineers, 2012, LAP Lambert Academics Publishing, ISBN 978-3846556771

Course Name- *Armour Protection Systems*

Course Code- *ME 613*

Course Outcome (COs):

- CO1** Understand the basics of different type of threats and structural design required for protection against these threats.

- CO2** Understand different type of Armours, soft kill and hard kill techniques. Evaluate different Armour Testing methods, NATO targets and Ballistic testing of Armour.
- CO3** Analyze different case studies related to Reactive protection, electric armour etc. Active protection system layout and integration to platform, Intercepting mechanism and apply the understanding to the design of future systems.
- CO4** Understand and evaluate the requirement of different Detection signature management techniques for acoustic, thermal, EM emissions etc. and proposing solution to the existing problems persisting currently.

Unit-I: Type of Threats: Threats to Armoured vehicles and systems. Frontal, top, side and bottom attacks. Armoured distribution on a typist MBT, ICV, body Armour.

Unit II: Structural Design and Protection: Structural requirements of armoured and nonarmoured vehicles; Armour Failure modes against Kinetic Energy (KE); Chemical Energy (CE).

Unit-III: Types of Armour: Small Armour and Splinters; Passive Armour - Rolled Homogenous Armour Steels, Aluminium Armour, Ceramic / Composite armour, Laminated / Spaced Armour, Explosive Reactive Armour; Active Armour - Soft Kill techniques and Hard Kill techniques.

Unit-IV: Armour Testing: NATO targets. Ballistic testing of Armour.

Unit-V: Case Studies: Reactive protection, explosive reactive Armour (ERA), Inert Reactive Armour (IRA), Electric Armour. Methods to detect ERA case studies. Active protection system, Layout and integration to platform, Sensors and control mechanism, Intercepting mechanism and case studies.

Unit-VI: Detection signature management: Signature Management for acoustic, Thermal, usual and EM emissions. Deceptions and decoys, Early warning systems, Camouflages and concealments.

Text Books/References:

1. Fighting vehicle, 1st edition, 1991, TW Terry, Jackson SR, Ryley CES and Wormell PJH, London: Brassey's
2. Jane's Armor and Artillery 2011-12, Christopher F Foss, IHS Janes, ISBN 0978-0710629609
3. Advances in Ceramic Armor II: Ceramic Engineering and Science Proceedings, 1st edition, 2006, Andrew Wereszczak, Edgar Lara Curzio and Lisa Prokurat Franks, Wiley, ISBN 0978-0470080573
4. Dynamic Behaviour of Materials, 1st edition, Marc Andrew Meyers, Wiley-Interscience, ISBN 0978-0471582625
5. Ballistic Impacts on Polymer Matrix Composites-Composite Armor: Personal Armor, 2011, R Zaera, Springer:Vienna, ISBN 0978-3709105221

Course Name- *Unmanned Ground vehicles*

Course Code- *ME 614*

Introduction to UGV, Classification of UGV, History /World Scan, Major Technologies Sub system of UGV, Mobile UGV Kinematics, Locomotion, Drive by wire technology, Planning & Navigation, Obstacle detection & warning system, Power supply system, Perception System, Payloads, Vehicle Platforms, Automatic Transmission, Controllers Tele operation, Sensors & Actuators, Allied Technology, Applications.

Text Books/References:

1. Autonomous Mobile Robots by Roland Siegwart, Illah R. Nour bakhsh, Davide Scaramuzza (Printice Hall)
2. Autonomous robots: From biological inspiration to implementation and control, By Bekey, G.A.

3. Intelligent unmanned ground vehicles- autonomous navigation research at carnegie mellon, By Hebert, M.H. Thorpe, C Stentz, A.
4. Robot technology fundamentals, by Keramas, J.G.
5. Principles of robot motion Theory algorithms and implementations by Choset, H. Lynch, K.M. Hutchinson, S. Kantor, G. Burgard, W. Kavraki, L.E. Thrun, S.

Course Name- *Trials & Evaluation of Weapon and Combat Systems*

Course Code- *ME 615*

Unit I: Weapon system requirements. Weapon performance characterization, firing environment and ambient conditions. Factors affecting accuracy and consistency. Statistical methods. Mean and standard deviation, Error estimation due to normal distribution, Probable Errors, test of hypothesis, Design of experiment. Acceptance testing.

Unit II: Static test procedures, Shock and vibration tests, Accelerated environmental tests. Closed vessel test. Conditioning chambers. Test methods for evaluation of safety. Static trials of warheads.

Unit III: Dynamic trials. Range and its layout, Safety distances and surface danger zones. Measurement. Instruments: Pressure, MV, Trajectory, Atmosphere data, High speed videography and motion picture analysis. In bore pressure measurement. Telemetry and Data Acquisition. Post trial Analysis. Range and Accuracy Trial. Functioning Trial. Recovery trial and inspection.

Unit IV: Combat Vehicle Evaluation Techniques - Automotive trials - Specialized test track for automotive trials; Weapon Trials - Special equipment for proving weapon, proving Ammunition and Proving Combat system as a whole; Different types of Trials - Development trials, User trials, Usage trials, Deployment trials.

Text Books/References:

1. Fighting vehicle, 1st edition, 1991, TW Terry, Jackson SR, Ryley CES and Wormell PJH, London: Brassey's
2. Surveillance and Target Acquisition Systems: Brassey's Land Warfare, 1997, MA Richardson, IC Luckraft and RF Powell, London: Brassey's, ISBN 978-1857531374
3. Statistical Methods, 2nd edition, 2003, Rudolph Freund and WJ Wilson, Academic Press Inc, ISBN 978-0122676512
4. Guided Weapons: Including Light, Unguided Anti-Tank Weapons, 3rd edition, 1998, RG Lee, TK Garland Collins, CA Sparkes and E Archer, London: Brassey's, ISBN 978-1857531527
5. Dynamic Systems: Modelling and Analysis, 1996, Ramin Esfandairi and Hung V Vu, Mc Graw Hill, ISBN 978-0072966619
6. Sensors: Advancements in Modelling, Design Issues, Fabrication and Practical Applications, 2008, Yueh-Min Ray Huang, Springer, ISBN 978-3540690306

Course Name- *Thermal Management of Defence Equipment*

Course Code- *ME 616*

Course Outcome (COs):

CO1 Understanding of Heat transfer fundamentals and heat generating electronic equipment

CO2 Understanding of methods used for thermal management of electronic equipment

CO3 Understanding of the basics aspects of compactness, scaling laws of heat exchanger, various types of heat exchanger. Apply thermal design concepts to Industrial compact heat exchangers using LMTD Method

Syllabus Details	Outcome
Unit I & II	CO1
Unit III	CO2
Unit IV	CO3

Unit I: Heat-transfer fundamentals: conduction, convection, radiation, phase change, and heat transfer across solid interfaces.

Unit II: Heat-generating electronic equipment: ICs, power converters, circuit cards and electrical connectors.

Unit III: Thermal management equipment: heat sinks, interface materials, heat spreaders including liquid loops, and air movers. System design: system packaging architectures, facilities, system analysis. Advanced Topics: spray cooling, refrigeration

Unit IV: Introduction, Basic aspect of compactness, Scaling laws of heat exchangers, surface optimization, Industrial compact heat exchangers: Plate Fin heat exchangers, Tube Fin heat exchangers, Printed Circuit heat exchangers, Plate and Frame heat exchangers, Spiral heat exchangers, Plate and Shell heat exchangers. Surface comparisons, Size, shape and weight relationships, Surface types and correlations, Thermal Design-LMTD method.

Text Books/References:

1. Compact Heat Exchangers- Selection, Design and Operation, John E. Hesselgreaves, Gulf Professional Publishing, 2001.
2. Compact Heat Exchangers: Allan D. Kraus, R. K. Shah Hemisphere Pub. Corporation, 1990.
3. Heat Transfer -Thermal Management of Electronic Systems, Y Shabany, CRC Press.

Course Name- *Kinematics and Dynamics of Machinery*

Course Code- *ME 617*

Course Outcomes (COs):

- CO1** Understand dynamics of machines, Equations of motion for a planar body, different types of forces
- CO2** Apply Balancing technique for achieving static balance
- CO3** Estimation of Inertia forces in a crank-slider mechanism

Unit I: Machine kinematics- Overview, Degrees of freedom, Links and joints, Grashof condition, 4-bar linkage, slider-crank, and inverted slider crank.

UNIT II: Dynamics of rigid bodies in plane motion, Dynamic force analysis of machines: Introduction to dynamics of machines, Equations of motion for a planar body, Equations for a mechanism Joint reaction, Different types of forces, Inverse dynamics- Determination of actuating forces, Forward dynamics – determination of accelerations given the actuating forces

UNIT III: Dynamics of rotating bodies: Unbalance in rotating machinery; Causes and effects of unbalance; Response of a simple rotor; Types of unbalances viz., static and dynamic; Balancing technique for achieving static balance; Balancing of rigid rotors; Two-plane method for balancing.

UNIT IV: Dynamics of Reciprocating Machines: Approximate acceleration analysis of an IC Engine mechanism, Equivalent Link model of a connecting rod, Estimation of Inertia forces in a crank-slider mechanism; Typical arrangements of multiple cylinders State of balance of typical multi-cylinder engines; The driving torque generated in an IC Engine due to gas forces; Issues in Matching of driving and load torques; Use of flywheels to smoothen the fluctuations in speed within a cycle.

Unit V: Programmable mechanisms- Introduction to industrial manipulators, Kinematic chains and classifications, Coordinate transformation, Forward and inverse kinematics

Text Books/References:

1. R. L. Norton, Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines, McGraw-Hill, current edition.

Course Name- *Composite Structures*

Course Code- *ME 618*

Course Outcomes (COs):

- CO1** Understand the basics of composite materials such as classification, characteristics, current and potential advantages and mechanical behavior of composites.
- CO2** Understand the micro-mechanical behavior of lamina. Evaluate Elastic Moduli of lamina. Apply constitutive equations of composite materials and evaluate engineering constants and analyze mechanical behavior at macro level.
- CO3** Analyze the macro-mechanical behavior of laminates and apply to the design of composite structures
- CO4** Understand the fabrication methods, testing and characterization of composites

Course Contents:

Unit I: Introduction composite materials-Classification and characteristics, mechanical behavior of composite materials, basic terminology, and manufacture of laminated fiber-reinforced composite materials, current and potential advantages of fiber-reinforced composite materials, applications of composite materials.

Unit II: Micro-mechanical behavior of lamina-Introduction, mechanics of materials approach to stiffness, elasticity approach to stiffness, comparison of approaches to stiffness, mechanics of materials approach to strength.

Unit III: Macro-mechanical behavior of lamina - Introduction, stress-strain relations for anisotropic materials, stiffnesses, compliances, and engineering constants for orthotropic materials, restrictions on engineering constants, stress strain relation for plane stress in an orthotropic material, stress-strain relations for lamina of arbitrary orientation, invariant properties of an orthotropic lamina, strengths of an orthographic lamina, biaxial strength criteria for an orthotropic lamina.

Unit IV: Macro-mechanical behavior of laminates-Introduction, Classical Lamination Theory, Special cases of Laminate stiffness, Theoretical versus Measured Stiffness, Strength of Laminates.

Unit V: Damage characteristics of laminated composites, Delamination in composites, Interlaminar stresses and free edge effects, design failure criteria for composite structures, experimental characterization of composites.

Text books:

1. Mechanics of composite materials, by Robert. M. Jones, second sediton, Taylor and Francis,1999.
2. Experimental characterization of advanced composites materials, third edition, Donald f Adams, Lief A. Carlsson and R. Byron pipes. CRC press.

Reference books:

1. Mechanics of fibrous composites by carl. T. Herakovich-john wiley and sons, 1997.55
2. Advanced composite materials, Lalit Gupta, Himalayan books. New delhi, 1998
3. Liquid moulding technologies, c d Rudd, a c long, k n Kendall and c g e Mangin, woodhead publishing limited, Cambridge England.
4. Process modeling in composites manufacturing, Suresh g advani, e. Murat sozer, Marcel Dekker, inc.

Course Name- *Tribology for Design*

Course Code- *ME 619*

Course Outcomes (COs):

- CO1** Understand the basics of Tribology, Lubrication and its modes and additives, Bearings and its terminologies, Friction laws, classifications, theories and measurement.
- CO2** Understand the Mechanics of Fluid Flow - Theory of hydrodynamic lubrication -Mechanism of pressure development in oil film, Two Dimensional Reynolds's Equation and its Limitations, Idealized Bearings, Infinitely Long Plane Fixed Sliders, Infinitely Long Plane Pivoted Sliders, Infinitely Long Journal Bearings, Infinitely Short Journal Bearings, Designing Journal Bearing-Sommerfeld number – Raimondi and Boyd method - Petroff's Solution - Parameters of bearing design - Unit pressure - Temperature rise - Length to diameter ratio - Radial clearance - Minimum oil-film thickness. Evaluate the load carrying capacity of the above-mentioned bearings.
- CO3** Understanding the basic of Hydrostatic and Squeeze Film Lubrication, Load carrying capacity and flow requirements, and its applications, Elasto-Hydrodynamic Lubrication principle and applications
- CO4** Understand Friction and Wear-Friction - Laws of friction - Friction classification - Causes of Friction, Theories of Dry Friction, Friction Measurement, Stick-Slip Motion and Friction Instabilities, Wear - Wear classification - Wear between solids – Wear between solid and liquid - Analyse the effects of various Factors affecting wear – Measurement of wear, Theories of Wear, Approaches to Friction Control and Wear Prevention

Course Contents:

Unit I: Introduction-Defining Tribology, Tribology in Design - Mechanical design of oil seals and gasket - Tribological design of oil seals and gasket, Tribology in Industry (Maintenance), Defining Lubrication, Basic Modes of Lubrication, Properties of Lubricants, Lubricant Additives, Defining

Bearing, Terminology - Sliding contact bearings -Rolling contact bearings, Comparison between Sliding and Rolling Contact Bearings

Unit II: Friction and Wear-Friction - Laws of friction - Friction classification - Causes of Friction, Theories of Dry Friction, Friction Measurement, Stick-Slip Motion and Friction Instabilities, Wear - Wear classification - Wear between solids – Wear between solid and liquid - Factors affecting wear – Measurement of wear, Theories of Wear, Approaches to Friction Control and Wear Prevention

Unit III: Lubrication of Bearings-Mechanics of Fluid Flow - Theory of hydrodynamic lubrication - Mechanism of pressure development in oil film, Two Dimensional Reynolds's Equation and its Limitations, Idealized Bearings, Infinitely Long Plane Fixed Sliders, Infinitely Long Plane Pivoted Sliders, Infinitely Long Journal Bearings, Infinitely Short Journal Bearings, Designing Journal Bearing- Sommerfeld number – Raimondi and Boyd method - Petroff's Solution - Parameters of bearing design - Unit pressure - Temperature rise - Length to diameter ratio - Radial clearance - Minimum oil-film thickness.

Unit IV: Hydrodynamic Thrust Bearing-Introduction - Flat plate thrust bearing - Tilting pad thrust bearing, Pressure Equation - Flat plate thrust bearing - Tilting pad thrust bearing, Load - Flat plate thrust bearing - Tilting pad thrust bearing, Center of Pressure - Flat plate thrust bearing - Tilting pad thrust bearing, Friction - Flat plate thrust bearing - Tilting pad thrust bearing

Unit V: Hydrostatic and Squeeze Film Lubrication-Hydrostatic Lubrication - Basic concept - Advantages and limitations - Viscous flow through rectangular slot – Load carrying capacity and flow requirement - Energy losses - Optimum design, Squeeze Film Lubrication - Basic concept - Squeeze action between circular and rectangular plates - Squeeze action under variable and alternating loads, Application to journal bearings, Piston Pin Lubrications.

Unit VI: Elasto-Hydrodynamic Lubrication-Principles and Applications, Pressure viscosity term in Reynolds's equation, Hertz's Theory, Ertel-Grubin equation, Lubrication of spheres, Gear teeth bearings, Rolling element bearings.

Unit VII: Gas (Air) Lubricated Bearings-Introduction, Merits, Demerits and Applications, tilting pad bearings, Magnetic recording, discs with flying head, Hydrostatic bearings with air lubrication, Hydrodynamic bearings with air lubrication, Thrust bearings with air lubrication.

Practice:

1. Surface roughness test,
2. Friction & Wear test on Pin on disc Machine
3. Case studies etc.

Text Books/References:

1. A. Harnoy, Bearing Design in Machinery, Marcel Dekker Inc, New York, 2003.
2. M.M. Khonsari & E.R. Booser, Applied Tribology, John Willey & Sons, New York, 2001.
3. E.P. Bowden and Tabor.D., Friction and Lubrication, Heinemann Educational Books Ltd., 1974.
4. A. Cameron, Basic Lubrication theory, Longman, U.K., 1981.
5. M.J. Neale (Editor), Tribology Handbook, Newnes. Butter worth, Heinemann, U.K., 1995.

Course Name- *High Energy Material Technology*

Course Code- *ME 620*

Unit I: High Energy Materials: An overview, Current trends and Future Directions, Characterization of High Energy Materials using Modern Instrumental Techniques.

Unit II: Solid Rocket Propellants: Introduction classification and specification of solid rocketpropellants, Ingredients, processing and performance of each class of propellants – Double base proellants (DBP) – Extruded, Fuel Rich Propellants (FRP), NEPE Propellants, Insulator-inhibitor-liner, X-ray radiography, Mechanical Characterization, Ignition system, Ballistic Prediction, Instrumentation for Static firing of Rockets, Future directions in development of solid rocket propellants.

Unit III: Gun Propellants: Introduction and Gun propellants developed in India, Classification, ingredients and manufacturing of gun propellants (SBP, DBP, TBP, LOVA), Combustible Cartridge Case for gun ammunition, Closed Vessel evaluation and Performance prediction of gun propellants, Future trends.

Unit IV: High Explosives: Introduction and uses, Classification and manufacture of high explosives, Theory of detonation and blast, Plastic Bonded explosives, explosive compositions for Low Intensity Conflict (LIC), Explosive Reactive Armour, Fuel – Air explosive, Thermobaric explosives compositon, Measurement and instrumentation.

Unit V: Pyrotechnics: Introduction, Classification and manufacture, Electro-explosive devices, Pyrotechnics smoke, Pyrotechic delays, Pyrotechnic Flares, Other devices, Instrumentation for performance measurement.

DETINICS, PBX & Insensitive Explosives.

Course Name- *Dynamics & Armament Mechanisms*

Course Code- *ME 621*

Unit I: Equation of motions, Frame of reference. Newtonia, Enterian, Langrangian, Hamiltonium formulation for motion dynamics. Euler angles and transformations. Translatory and Rotary motions. Constraint and unconstraint motion.

Unit II: Mechanisms: Linear, Rotary, Hydraulic and Pneumatic systems.

System dynamics for first and second order systems and response in time and frequency domain.

Unit III: Mechanisms of large Calibre Weapons: Balancing gear, Breech and Firing Mechanisms, Recoil Mechanisms, Laying Mechanisms, Ramming Mechanisms.

Unit IV: Small Arms Mechanisms: Introduction, Operating Mechanisms (Blow back, recoil and Gas operated), Feeding Mechanisms, Trigger and Firing Mechanisms, Ejection and Extraction Mechanisms.

Unit V: Fuze Mechanisms: Safety and Arming Mechanism, Spring Mass Mechanisms, Rotary Mechanisms, Clock work Mechanisms.

Launcher Platform Leveling, Laying, Sighting, Rocket Pinaka, Control Mechanisms.

Course Name- *Ballistics of Bombs & Projectiles*

Course Code- *ME 622*

Unit I: Basics of Ballistics of any projectile, Difference between precision, accuracy and CEP.

Unit II: Internal Ballistics (Guns): Burning of propellants, Vielle's mode and rate of burnings, form function, Resalls' Energy Equation. Internal ballistic solutions, Hunt hind Heydenreigh system. Lodue Method. Effect of vibrations in loading conditions, Similarity relations.

Unit III: External Ballistics (Guns): Aerodynamic force system. Normal equations. Siacci form of solutions, Numerical methods of trajectory computation, Meteorological corrections. Angular motion of the Centre of mass. Drift and deflection, Dispersion of fire.

Unit IV: External Ballistics of Rockets: Launch dynamics, plane trajectory, boost plane trajectory models, rocket accuracy (dispersion and stability), rocket-assisted projectiles.

Unit V: Bomb Ballistics: Aerodynamic forces and moments acting on a bomb, Drag co-efficient, Terminal velocity and Ballistic index, Trajectory of bombs, Simulated stores (similitude) and their trajectories, Bomb stability derivatives and analysis (in roll, pitch and yaw), wind tunnel testing, Bomb trajectory calculations with point mass and Six Degrees of Freedom Equations. Calculation of Moment of Inertia and Centre of Gravity of bombs.

Text Books/References:

1. Text Book of Ballistic & Gunnery, 1987, Vol I & II, HMSO Publication.
2. DE Carlucci & SS Jacobson Ballistics Theory and Design of Guns & Ammunition, 2007, CRC Press.
3. Military Ballistics: A Basic Manual (Brassey's New Battlefield Weapons Systems and Technology Series into 21st Century), 1999, CL Farrar, DW Leeming, GM Moss, Brassey's (UK) Ltd. Robert L McCoy Modern Exterior Ballistics, 2001, , Schiffer Publishing.

Course Name- *Design of Ordnance, Basic and Super Structure*

Course Code- *ME 623*

Unit I: Gun Barrel and Tube Launcher: Theory of failure, Gun Barrel Design, Material and Manufacturing by VAR, ESR, etc. Proof of ordnance, Design of Combustion Chambers. Gun tube acoustics.

Unit II: Breech Mechanism: Principles of operation and design of Muzzle Brakes, Fume Extractors and Firing Mechanisms

Unit III: Design of Structural Elements: Design of gun superstructure and basic structures. Curvilinear and soft recoil systems, articulation and suspension systems.

Text Books/References:

1. "Engineering Design Hand Book: Recoil Systems", AMC Pamphlets, Washington, 1978
2. Thomas J. Hayes, "Elements of ordnance", John Wiley, New York, 1952
3. "Engineering Design Hand Book: Recoil; Elevating and Traversing mechanisms; Cradles; Top carriage; Bottom Carriage and Muzzle Devices", AMC Pamphlets, Washington, 1968.

Course Name- *Small Arms and Cannons*

Course Code- *ME 624*

Unit I: Introduction: Classification, Characteristics and Operating Principles. Automatic Fire and Power Source. Principles and Factors affecting the choice and Design of Projectile and Weapon; Heating of Small Arms; Accuracy and Chance of Hit.

Unit II: Operating Principles: Analytical and Comparative Study of Blowback, Recoil and Gas Operation systems, and Externally Driven Weapon Systems.

Unit III: Subsystems: Feed Systems, Trigger and Firing Systems, Extraction and Ejection Systems, Locking and Mechanical Safety and Muzzle Attachments.

Manufacturing; Inspection; Life Estimation; Modern Trends; Typical Weapon Study: INSAS.

Text Books/References:

1. "Handbook of Infantry Weapons", Part – 1, RMCS, UK, 1987
2. D Allsop, L Popelinsky et al, "Brassy's Essential Guide to Military Small Arms: Design Principles and Operating Methods", Brassy's, UK, 1997
3. "Engineering Design Handbook: Automatic Weapons", AMC Pamphlet No. 706 – 260, US Army Material Command, Washington, 1970

Course Name- *Combat Vehicle Technology*

Course Code- *ME 625*

Unit I: AFV Characteristics : Concept of Tank warfare and design philosophies of AFVs, Development of Tanks, Design parameters of combat vehicles to include configuration, overall dimensions etc.

Unit II: Firepower : Characteristics, components, main gun and tank ammunition including ATGMs, secondary armament, Ranging & Sighting systems including NVD, GCE & ALG, Probability of Kill, Errors & Biases, Fire Control system.

Unit III: Mobility : Types, performance parameters, obstacle crossing ability, navigation – GPS & GLNS.

Unit IV: Protection : Types, Armour Protection, Active protection systems, Protection against NBC and Fire.

Tank communication & IFF, Maintainability, Availability, Reliability and Ergonomics.

Unit V: Critical Dimensions and Design : Steerability ratio, Track Width, Pitch ratio, NGP , MMP, Angle of approach and Angle of departure, Pitch of tank, No of Road Wheels, Inter-relation between all dimensions and Design requirements.

Unit VI: Latest Trends, FMBT, FICV, Lt Tank, AFV Variants

Text Books/References:

1. Fighting vehicle, 1st edition, 1991, TW Terry, Jackson SR, Ryley CES and Wormell PJH, London: Brassey's
2. Ballistics: Theory and Design of Gun and Ammunition, 2007, Donald E Carlucci and Sidney S Jacobson, CRC Press, ISBN 978-1420066180
3. Fundamentals of Vehicle Dynamics, Thomas D Gillespie, SAE International, ISBN 978-1560911999
4. Terramechanics and Off-road Vehicle Engineering: Terrain Behaviour, Off-Road Performance and Design, 2nd edition, J.Y. Wong, Butterworth Hienemann
5. Jane's Armor and Artillery 2011-12, Christopher F Foss, IHS Janes, ISBN 978-0710629609
6. Dynamic Behaviour of Materials, 1st edition, Marc Andrew Meyers, Wiley-Interscience, ISBN 978-0471582625
7. Projectile Impact: Modelling Techniques and Assessment of Target Material Performance, 2014, S Syngellakis, Wit Pr, ISBN 978-1845648794
8. Protection Levels for Occupants of Logistic and Light Armored Vehicles, NATOSTANAG 4569

Course Name- *Vehicle Dynamics*

Course Code- *ME 626*

Unit I: Vehicle Ride: Human response to vibration, ISO standards, Response of idealized suspension systems to stop and sinusoidal disturbance in bounce and to wheel out of balance. Combined pitch and bounce motion, application to multi wheel station vehicles. Random ground input excitation, use of sinusoidal transmissibility function to predict mean square motion of spring mass. Vehicle performance during cornering, Dynamic Vibration Absorber.

Unit II: Wheeled Vehicle: Vehicle transfer function. Kinematic behaviour of vehicles with rigid wheels and with compliant tyres, neutral steer point, static margin, over and under steer. Derivation of generalized equations of motion for a vehicle, stability derivative notation. Solution with two degree of freedom in the steady in yaw. Frequency response in yaw. Extension of two degree of freedom theory to include effects of traction and braking, self-aligning torque, dual wheels and bogies. Development of equations of motion to include roll of sprung mass, Effect on steady state and frequency response.

Unit III: Tracked Vehicle Handling: Analysis of sprocket torques and speeds, required to skid steer a tracked vehicle. Modification of theory to allow for soil conditions and lateral Weight transfer. Application of theory of steering of articulated and half – track vehicles.

Unit IV: Terrmechanics: Nature of soil vehicle interaction, Characteristics of soil and bearing capacity, Empirical approaches for prediction of vehicle mobility.

Text Books/References:

1. Fundamentals of Vehicle Dynamics, Thomas D Gillespie, SAE International, ISBN 978-1560911999
2. Automotive Handbook, 8th edition, Robert Bosch GmbH, Wiley Blackwell, ISBN 978-0837516865
3. A Textbook of Automobile Engineering-II, P.S.Gill, Katson Books, ISBN 978-9350140420
4. Automotive Transmission-Fundamentals, Selection, Design & Application, Giesbert Lechner and Herald Naunheimer, Springer, ISBN 978-3540659037
5. Theory of Ground Vehicles, 4th edition, J.Y.Wong, John Wiley & Sons, ISBN 978-0470170387
6. Shock Absorber Handbook, John.C.Dixon, SAE International, ISBN 978-0768018431
7. Car Suspension and Handling, 4th edition, Geoffrey Howard, Donald Bastow and John Peter Whitehead, SAE International, ISBN 978-0768008722
8. Terramechanics and Off-road Vehicle Engineering: Terrain Behaviour, Off-Road Performance and Design, 2nd edition, J.Y.Wong, Butterworth Hienemann
9. Heavy-Duty Wheeled Vehicles: Design, Theory & Calculation, Boris Nikolaevich Belousov and Sergey.D.Popov, SAE International, ISBN 978-0768077230

Course Name- *Fatigue and Fracture Mechanics*

Course Code- *ME 627*

Course Outcomes (COs):

- CO1** Understand the fatigue failure of structures, physical aspects of fatigue, phase in fatigue life, fatigue fracture surfaces, statistical aspects of fatigue behaviors.
- CO2** Understand fatigue failure Criteria such as Goodman, Gerber and Soderberg relations and diagram, apply failure criteria and evaluate factor of safety to predict the safety of structure under operating loads. Apply Miner's theory and other theories and evaluate life of structure under different loads for different no of cycles.

- CO3** Understand fracture mechanics design concept. Analyze the fracture mechanics strength of cracked bodies. Evaluate stress intensity factors for typical geometries. Analyze effect of thickness on fracture toughness.
- CO4** Understand the fatigue design and testing, safe life and fail-safe design philosophies, application to composite materials and structures. Evaluation of life of structures with damages.

Course Contents:

Unit I: Fatigue of Structures-S.N. curves - Endurance limits - Effect of mean stress, Goodman, Gerber and Soderberg relations and diagrams - Notches and stress concentrations - Neuber's stress concentration factors-Plastic stress concentration factors - Notched S.N. curves.

Unit II: Statistical Aspects of Fatigue Behaviour-Low cycle and high cycle fatigue - Coffin - Manson's relation - Transition life - cyclic strain hardening and softening - Analysis of load histories - Cycle counting techniques -Cumulative damage - Miner's theory - Other theories.

Unit III: Physical Aspects of Fatigue-Phase in fatigue life - Crack initiation - Crack growth - Final Fracture - Dislocations - fatigue fracture surfaces.

Unit IV: Fracture Mechanics-Strength of cracked bodies - Potential energy and surface energy - Griffith's theory - Irwin - Orwin extension of Griffith's theory to ductile materials - stress analysis of cracked bodies - Effect of thickness on fracture toughness - stress intensity factors for typical geometries.

Unit V: Fatigue Design and Testing-Safe life and Fail-safe design philosophies - Importance of Fracture Mechanics in aerospace structures - Application to composite materials and structures.

Text Books/References:

1. Prashanth Kumar, Elements of fracture mechanics, Wheeter publication, 1999.
2. Barrois W, Ripely, E.L., Fatigue of aircraft structure, Pe/gamon press. Oxford, 1983.
3. Knott, J.F., Fundamentals of Fracture Mechanics, Buterworth& Co., Ltd., London, 1983.
4. David Broek, Elementary Engineering Fracture Mechanics, Kluwer Academic Publishers,1986.

Course Name- *Design of Hydraulic and Pneumatic Systems*

Course Code- *ME 628*

Course Outcomes (COs):

CO1 Students will be able to **explain, analyze and apply** basics of hydraulic systems and components

CO2 Students will be able to **analyze and design** hydraulic circuits.

CO3 Students will be able to **explain, analyze and apply** basics of pneumatic systems and components

CO4 Students will be able to **analyze and design** pneumatic circuits.

Course Contents:

Unit I: Hydraulic System & Components-Sources of Hydraulic Power: Pumping theory – Pump classification – Gear pump, Vane Pump, piston pump, construction and working of pumps – pump performance – Variable displacement pumps. Fluid Power Actuators: Linear hydraulic actuators – Types of hydraulic cylinders – Single acting, Double acting special cylinders like tanden, Rodless, Telescopic, Cushioning mechanism, Construction of double acting cylinder, Rotary actuators – Fluid motors, Gear, Vane and Piston motors

Unit II: Design of Hydraulic Circuits-Construction of Control Components: Director control valve – 3/2-way valve – 4/2-way valve – Shuttle valve – check valve – pressure control valve – pressure reducing

valve, sequence valve, Flow control valve – Fixed and adjustable, electrical control solenoid valves, Relays, ladder diagram. Accumulators and Intensifiers: Types of accumulators – Accumulators circuits, sizing of accumulators, intensifier – Applications of Intensifier – Intensifier circuit.

Unit III: Pneumatic Systems and Components-Pneumatic Components: Properties of air – Compressors – Filter, Regulator, and Lubricator Unit – Air control valves, Quick exhaust valves, and pneumatic actuators. Fluid Power Circuit Design, Speed control circuits, synchronizing circuit, Penumo hydraulic circuit, Sequential circuit design for simple applications using cascade method.

Unit IV: Design of Pneumatic Circuits-Servo systems – Hydro Mechanical servo systems, Electro hydraulic servo systems and proportional valves. Fluidics – Introduction to fluidic devices, simple circuits, Introduction to Electro Hydraulic Pneumatic logic circuits, ladder diagrams, PLC applications in fluid power control. Fluid power circuits; failure and troubleshooting.

Text Books:

1. Anthony Esposito, Fluid Power with Applications, Pearson Education 2000.
2. Majumdar S.R., Oil Hydraulics, Tata McGraw-Hill, 2000.
3. Johnson, James L., Introduction to Fluid Power, Delmar Publishers, 2003

Reference Books:

4. Majumdar S.R., Pneumatic systems – Principles and maintenance, Tata McGraw Hill, 1995
5. Harry L. Stevart D.B, Practical guide to fluid power, Taraoeala sons and Port Ltd. Broadey, 1976.
6. Michael J, Prinches and Ashby J. G, Power Hydraulics, Prentice Hall, 1989.
7. Dudelyt, A. Pease and John T. Pippenger, Basic Fluid Power, Prentice Hall, 1987.

Course Name- *Design of Machinery*

Course Code- *ME 630*

Course Outcomes (COs):

- CO1** Determine the kinematic chain and mobility, and perform the kinematic analysis of a given mechanism.
- CO2** Identify the basic relations between distance, time, velocity, and acceleration and apply the fundamental principles of statics and dynamics to machinery
- CO3** Understand and avoid/suppress certain common dynamical problems a machine may undergo and Apply vector mechanics as a tool for solving kinematic problems
- CO4** Understand the fundamentals of machine design for desired kinematic or dynamic performance and use graphical and analytic methods to study the motion of a planar mechanism.

Course Contents:

Unit I: Introduction- Classification of mechanisms – Basic kinematic concepts and definitions – Degree of freedom, Mobility – Kutzbach criterion, Gruebler's criterion – Grashof's Law – Kinematic inversions of four-bar chain and slider crank chains – Limit positions – Mechanical advantage – Transmission Angle – Description of some common mechanisms – Quick return mechanisms, Straight line generators, Universal Joint – rocker mechanisms.

Unit II: Kinematics of mechanisms/machineries- Displacement, velocity and acceleration analysis of simple mechanisms – Graphical method– Velocity and acceleration polygons – Velocity analysis using instantaneous centres – kinematic analysis of simple mechanisms – Coincident points – Coriolis component of Acceleration – Introduction to linkage synthesis problem.

Unit III: Dynamics of mechanisms/machineries-Dynamics Fundamentals, Dynamic Force Analysis, Balancing, Engine Dynamics, Multi cylinder Engines.

Unit IV: Kinematic and dynamic analysis of machine components- Classification of cams and followers – Terminology and definitions – Displacement diagrams –Uniform velocity, parabolic, simple harmonic and cycloidal motions – Derivatives of follower motions – Layout of plate cam profiles – Specified contour cams – Circular arc and tangent cams – Pressure angle and undercutting – sizing of cams.

Law of toothed gearing – Involute and cycloidal tooth profiles –Spur Gear terminology and definitions –Gear tooth action – contact ratio – Interference and undercutting. Helical, Bevel, Worm, Rack and Pinion gears [Basics only]. Gear trains – Speed ratio, train value – Parallel axis gear trains – Epicyclic Gear Trains.

Case Studies on design and development of models

Text Books/References:

1. R L Norton, Design of Machineries, 5th Edition, McGraw Hill Publishers.
2. Uicker, J.J., Pennock G.R and Shigley, J.E., Theory of Machines and Mechanisms, 3rd Edition, Oxford University Press, 2009.
3. Rattan, S.S, Theory of Machines, 3rd Edition, Tata McGraw-Hill, 2009.
4. Thomas Bevan, Theory of Machines, 3rd Edition, CBS Publishers and Distributors, 2005.
5. Cleghorn. W. L, Mechanisms of Machines, Oxford University Press, 2005.
6. Allen S. Hall Jr., Kinematics and Linkage Design, Prentice Hall, 1961.
7. Ghosh. A and Mallick, A.K., Theory of Mechanisms and Machines, Affiliated East West Pvt. Ltd., New Delhi, 1988.
8. Rao.J.S. and Duggipati.R.V. Mechanisms and Machine Theory, Wiley-Eastern Ltd., New Delhi, 1992.

Course Name- *Product Design and Development*

Course Code- *ME 631*

Course Outcomes (COs):

- CO1** Apply methods for collection of customer requirements and for formulating product requirements
- CO2** Select an appropriate product design and development process for a given application
- CO3** Choose an appropriate ergonomics for the product
- CO4** Develop methods to minimize the cost.
- CO5** Understand the importance of AM in product design and development.

Course Contents:

Unit 1: Introduction: Classification/ Specifications of Products. Product life cycle. Product mix. Introduction to product design. Modern product development process. Innovative thinking. Morphology of design. Conceptual Design: Generation, selection & realisation of concept. Product architecture. Industrial design: Need and process. Robust Design: Taguchi Designs & DOE. Design Optimization.

Unit II: Ergonomics and Aesthetics: Gross human anatomy. Anthropometry. Man-Machine interaction. Concepts of size and texture, colour. Comfort criteria. Psychological & Physiological considerations. Creativity Techniques: Creative thinking, conceptualization, brain storming, primary design, drawing, simulation, detail design. Value Engineering and Value Analysis: Definition and basic concepts only. Economic analysis (Basic concepts): Qualitative & Quantitative. Product costing.

Unit III: Design for Manufacturing & Assembly: Methods of designing for Manufacturing & Assembly. Designs for Maintainability. Designs for Environment. Legal factors and social issues. Engineering ethics and issues of society related to design of products. Basic concepts of Concurrent Engineering, Tools for product design – Drafting / Modelling software. QFD. CAM Interface. Overview of Patents & IP Acts. Report generation.

Unit IV: Design Thinking of Emphasis on the powerful process of innovative problem solving which begins with latent/ unmet customer needs with a process of innovation to converge on enhancing success rate of innovation.

Unit V: Introduction to Additive Manufacturing (AM) and Rapid Prototyping

- o Different AM processes & process chain
- o Application level: Direct processes; Rapid Prototyping, Rapid Tooling. Rapid Manufacturing; Indirect Processes - Indirect Prototyping.
- o Reverse engineering
- o Impact of AM on “Time to market”

Text Books/References:

1. Ashby, M. F. “Materials Selection in Mechanical Design”, Pergaman Press, 1992.
2. Bralla J., “Handbook of Product Design for Manufacture”, McGraw Hill, 1988.
3. Levy S., and Dubois, L. H, “Plastics Production Design Engineering Handbook, Methuen Inc., 1985.
4. Dieter G E, Engineering Desing, McGraw-Hill, 1991.
5. YotaroHatamura, The Practice of Machine Design, Claredon Press Oxfor, 1999.
6. ErtasAtilia and Jones J C, The Engineering Design Process, John Wiley & Sons, 1996.
7. Waldron B M and Kenneth J W, Mechanical Design: Theory and Methodology, Sprriinger, 1996.
8. Ian Gibson, David W. Rosen and Brent Stucker, Additive manufacturing technologies: rapid prototyping to direct digital manufacturing, Springer, 2010.

Course Name- *Experimental Stress Analysis*

Course Code- *ME 634*

Course Outcomes (COs):

- CO1** Understand Principles of measurements, Accuracy, Sensitivity and range of measurements. Mechanical, Optical Acoustical and Electrical extensometers
- CO2** Apply Wheatstone bridge and potentiometer circuits for static and dynamic strain measurements, strain indicators.
- CO3** Evaluate stresses using photoelastic effects, stress optic law and with Interpretation of fringe patterns

Course Contents:

Unit I: Measurements & Extensometer-Principles of measurements, Accuracy, Sensitivity and range of measurements. Mechanical, Optical Acoustical and Electrical extensometers and their uses, Advantages and disadvantages.

Unit II: Electrical Resistance Strain Gauges-Principle of operation and requirements, Types and their uses, Materials for strain gauge. Calibration and temperature compensation, cross sensitivity, Rosette analysis, Wheatstone bridge and potentiometer circuits for static and dynamic strain measurements, strain indicators.

Unit III: Photoelasticity-Two-dimensional photo elasticity, Concept of light – photoelastic effects, stress optic law, Interpretation of fringe pattern, Compensation and separation techniques, Photo elastic materials. Introduction to three-dimensional photo elasticity.

Unit IV: Brittle Coating and Moire Methods-Introduction to Moire techniques, brittle coating methods and holography.

Unit V: Non-Destructive Testing-Fundamentals of NDT, Radiography, ultrasonic, magnetic particle inspection, fluorescent penetrant technique, Eddy current testing, Acoustic Emission Technique.

Text Books:

1. Srinath, L.S., Raghava, M.R., Lingaiah, K., Garagesha, G., Pant B., and Ramachandra, K., Experimental Stress Analysis, Tata McGraw-Hill, New Delhi, 1984.

Reference Books:

1. Dally, J.W., and Riley, W.F., Experimental Stress Analysis, McGraw-Hill Inc., New York, 2005, IV edition.
2. Hetenyi, M., Hand book of Experimental Stress Analysis, John Wiley and Sons Inc., New York, 1972.
3. Pollock A.A., Acoustic Emission in Acoustics and Vibration Progress, Ed. Stephens R.W.B., Chapman and Hall, 1993.

Course Name- MEMS - Design, Fabrication, and Characterization

Course Code- ME 636

Course Outcomes (COs):

CO1 Understand Basic concepts of design of MEMS devices and processes, Design for fabrication

CO2 Analyze MEMS devices

CO3 Evaluation of various parameters through MEMS Characterization

Course Contents:

Unit I: MEMS Fabrication-Conventional MEMS fabrication using VLSI technology: lithography, chemical etching: isotropic and anisotropic, Plasma etching, reactive ion etching (RIE), oxidation, chemical vapour deposition (CVD), LPCVD, PECVD, surface micromachining, LIGA, single layer and higher layer fabrication. Non-conventional MEMS fabrication: laser micromachining and welding, processing of metals and nonmetals with laser, Electro Discharge and Electro Chemical micromachining (EDM and ECM), Microstereolithography: scanning process, dynamic mask process. Electronic packaging.

Unit II: MEMS: Design and Analysis-Basic concepts of design of MEMS devices and processes, Design for fabrication, other design considerations, Analysis of MEMS devices, FEM and Multiphysics analysis, Modeling and simulation, connection between molecular and continuum mechanics, MEM system level analysis from perspective of control theory.

Unit III: MEMS Characterization-Technologies for MEMS characterization, Scanning Probe Microscopy (SPM): Atomic Force, Microscopy (AFM), Scanning tunnelling microscopy (STM), Magnetic Force Microscopy, Scanning Electron Microscope, Laser Doppler vibrometer, Electronic Speckle Interference Pattern technology (ESPI). Examples and case studies: Comb actuator for nano positioning stage by POLYMUMPS process.

Text Books/References:

1. Nadim Maluf, An Introduction to Microelectromechanical Systems Engineering, Artech House, Boston, 2000.
2. Stephen D. Senturia, Microsystems Design, Kluwer Academic Publishers, New York, November 2000
3. S. M. Sze, VLSI Technology, McGraw-Hill International Editions, Singapore, 1988.
4. M. Elwenspoek and H. Jansen, Silicon Micromachining, Cambridge University Press, Cambridge, UK, 1998.
5. Norio Taniguchi, editor Nanotechnology, Oxford University Press, Oxford, UK, 2003.
6. Joseph McGeough, editor Micromachining of Engineering Materials, Marcel Dekker, Inc., New York, 2002.
7. Marc Madou, "Fundamentals of Microfabrication: The science of miniaturization," CRC Press, LLC, 2002.

Course Name- *Design of Pressure Vessels***Course Code- *ME 637*****Course Outcomes:**

- CO1** Students will be able to **explain & analyze** methods to evaluate stresses generated in pressure vessels
- CO2** Students will be able to **analyze and design** for stresses generated in different components of different shapes of pressure vessels.
- CO3** Students will be able to **analyze and design** pressure vessels using ASME design codes
- CO4** Students will be able to **analyze and apply** concepts related to buckling of pressure vessels under different load conditions.

Course Contents:

Unit I: Introduction-Methods for determining stresses – Terminology and Ligament Efficiency – Applications.

Unit II: Stresses in Pressure Vessels-Introduction – Stresses in a circular ring, cylinder – Membrane stress Analysis of Vessel Shell components – Cylindrical shells, spherical Heads, conical heads – Thermal Stresses – Discontinuity stresses in pressure vessels.

Unit III: Design of Vessels-Design of Tall cylindrical self-supporting process columns –Supports for short, vertical and horizontal vessels – stress concentration – at a variable Thickness transition section in a cylindrical vessel, about a circular hole, elliptical openings. Theory of Reinforcement – pressure vessel Design. Introduction to ASME pressure vessel codes

Unit IV: Buckling of Vessels-Buckling phenomenon – Elastic Buckling of circular ring and cylinders under external pressure – collapse of thick-walled cylinders or tubes under external pressure – Effect of supports on Elastic Buckling of Cylinders – Buckling under combined External pressure and axial loading.

Text Books/References:

1. John F. Harvey, Theory and Design of Pressure Vessels, CBS Publishers and Distributors, 1987.
2. Henry H. Bedner, Pressure Vessels, Design Hand Book, CBS publishers and Distributors, 1987.

3. Stanley, M. Wales, Chemical process equipment, selection and Design. Butterworths series in Chemical Engineering, 1988.
4. William. J., Bees, Approximate Methods in the Design and Analysis of Pressure Vessels and Piping, PreASME Pressure Vessels and Piping Conference, 1997.

Course Name- Warship Transmission and Tribology

Course Code- ME 641

Course Outcome:

- CO1** Students will be able to **analyze and apply** basics of power transfer in Marine gear boxes, stresses, noise and modes of failure in gear drives
- CO2** Students will be able to **explain** about Navel standards used in design of shafting in marine engines transmission systems.
- CO3** Student will **understand** basics of tribology, modern lubricants used in marine engines
- CO4** Students will be able to **analyze & apply** different types of hydrodynamic bearings starting from basic governing equations and evaluate load bearing and frictional losses

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO2
Unit III	CO3
Unit IV	CO4

Unit I: Warship Transmission Design- Classification of gears, Spur and helical gear Specifications, Conjugate action, Involute and cycloidal gears, change of center distance, Gear trains, Gear Tooth loads, Bearing loads, Reaction torque, Lewis equation, AGAM Stress correction factors, Design of spur & helical gears, Gear noise, Causes and classification of gear failures.

Unit II: NES requirements- Shafting (NES requirements, torsional and bending strength calculations), Shaft-line Bearings (NES requirements, types, numbers and load distribution), Design checks of Marine Gearboxes.

Unit III: Tribology- Friction, wear and lubrication, Theory of wear, types and mitigation strategies, Theory of hydrodynamic lubrication, properties of marine lubricants.

Unit IV: Journal Bearings- Classification, selection and performance, Theories of design of Journal Bearings: Load & frictional loss evaluation for Plain slider, Step and full journal bearing, Petroff equation, Reynolds Equation

Text Books/References:

1. Engineering Tribology, GW Stachowiak, AW Batchelor, Butterworth Heinman, 2001.
2. Shigley's Mechanical Engineering Design [In SI Units], Joseph Shigley, Charles Mischke, Richard Budynas, Keith Nisbett, Tata McGraw Hill, 2008.
3. Schaum's Outline of Machine Design, 3rd Ed, Tata McGraw Hill, 2010.
4. Gear Engineering, Pitman, Merritt HE, Latest edition.

Course Name- Automatic Control Systems

Course Code- ME 642**Course Outcome:**

- CO1** Students will understand basics of control systems like transfer function, closed/open systems, feedback & feed forward systems & draw block diagrams for mechanical, electrical and hydraulic systems
- CO2** Students will understand Nyquist criterion, static & dynamic characteristics of transient, steady state, 1st/2nd order control systems using frequency response, stability analysis, root locus analysis.
- CO3** Students will understand control system actions & components like discrete/proportional, integral & differential control actions, comparators & actuators, amplifiers, servo motors, control valves
- CO4** Students will be able to apply control system basics to pneumatic, hydraulic & electrical systems based on microprocessor, PLC, micro-controller based distributed Marine control systems

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO2
Unit III	CO3
Unit IV & V	CO4

Unit I: Basic concepts of Automatic Control- Transfer Functions-Modeling of systems- Mechanical, Electrical, hydraulic system block diagram, signal flow graphs, closed and open loop systems. Feedback and Feed forward control system.

Unit II: Static and Dynamic Characteristics of Control Systems- Transient Response and Steady state error analysis for First and second order systems. Frequency response. Experimental determination of transfer function. Stability Analysis. Root Locus Analysis. Nyquist Criteria.

Unit III: Control Actions and Control System Components- Discrete action, Proportional, Integral and Differential Control Action, Composite action. Characteristics, working and limitations of different types of Comparators and actuators, amplifiers, Servo motors and Control valves.

Unit IV: Control System Implementations- Pneumatic Systems, Hydraulic Systems, Electrical Systems, Microprocessor Based Systems, Programmable Logic Controllers, Micro Controllers and Network Based Distributed Control Systems,

Unit V: Case Studies- Marine Systems (for Naval Students): Integrated Platform Management System / Battle Damage Control System, Ship board digital control, architecture and implementation of control of Marine systems in the latest Indian Naval Surface Warships.

Mechanical Systems (for Non - Naval Students): Engine auto control warning system, NBC & fire fighting systems, Remote vehicles.

Texts Books:

- Measurement System, Application & Design, 4thEd, E O Doebelin, Mc Graw Hill, 2003.
- Modern Control Engineering, 4th Ed, Katushiko Ogata, Pearson, UK, 2001.
- Modern Control Engineering, 4th Ed, Katushiko Ogata, Pearson, UK, 2001.

Course Name- *Ship Dynamics and Marine Systems*

Course Code- *ME 643*

Course Outcome:

CO1 Students will be able to explain & apply basics of ship structure, stability and design

CO2 Students will be able to analyze, explain & apply procedures for Staff requirements and procurement of main and auxiliary machineries

CO3 Students will be able to explain & apply basics of marine systems like Distillation & Desalination Plants, Power Generation, Air conditioning & Refrigeration

CO4 Students will be able to explain & apply Damage Control, NBCD requirements, Instrumentation and controls of a ship

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO2
Unit III	CO3
Unit IV	CO4

Unit I: Introduction to Naval Architecture and Ship Dynamics- Categorization of ships, ships geometry and hydrostatics, Properties of ship building materials, Strength and structure of ship's hydrostatics and initial stability. Intact and Damage Stability. Ship Powering Calculations and Propeller design.

Unit II: Staff Requirements for new ship design- Formulation of requirements, general role, speed, endurance, armament, logistic requirements, procedure for formulating outline, agreed and approved staff requirements, procedure for finalization of ship designs. Choice & Selection of Propulsion System and Auxiliaries

Unit III: General requirements of marine machinery Design for shock protection. Types of main propulsion and their evaluation. Selection of Distillation & Desalination Plants, Power Generation, Air conditioning & Refrigeration, Ships Systems,

Unit IV: NBCD Requirements, Marine Controls and Instrumentation.

Texts Books

- 1 Introduction to Naval Architecture, TC Gilmer, Bruce Johnson, Naval Institute Press, 1982.
- 2 Basic Ship Theory, Vol I & II, Rawson & Tupper, Saint Louis, Butterworth Heineman, 1994.
- 3 Warship Propulsion System Selection, CM Plumb, The Institute of Marine Engineers, 1987.

Course Name- *Marine Diesel Engines*

Course Code- *ME 644*

Course Outcome:

CO1 Students will be able to **analyze & apply** thermodynammic 1st law and 2nd law analysis to ideal combustion process and **explain** turbocharging and in marine diesel engine

CO2 Students will be able to **analyze and explain** factors affecting diesel engine performance and effect of design parameter

CO3 Students will be able to **analyze, apply and explain** Marine Diesel Engine rating, selection & engine-propeller matching

CO4 Student will be able **analyze and explain** regulations & control Mechanisms for noise and emissions from marine diesel engines

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO2
Unit III	CO3
Unit IV	CO4

Unit I: Thermodynamic Concepts- Fuel and their properties; basic thermodynamics of ideal gas mixtures; First law and Second law of thermodynamics applied to combustion, Turbocharging and Supercharging.

Unit II: Diesel Engine working and performance: CI engine combustion process; conceptual CI engine combustion models; combustion process characterization. Fuel injection: spray structure, atomization, penetration, drop size distribution, and evaporation; Factors affecting Ignition delay; Mixing controlled combustion; heat release rates; Effect of engine design variables, swirl, and injection rates.

Unit III: Marine Diesel Engine rating, selection, engine-propeller matching- Terminology, Service Rating, Corrections for ambient conditions, Diesel engine Characteristics, Principles of matching, Modifications to allow for Service conditions, Towing Loads, Auxiliary Loads, CPP.

Unit IV: Noise and Emission Reduction in marine diesel engines- Regulations, Constituents, Control Mechanisms for reduction of noise and exhaust emissions from marine diesel engines.

Texts Books

1. Internal Combustion Engine Fundamentals, JB Heywood, McGraw Hill , 2003.
2. Internal Combustion Engine Theory and Practices, 2nd Ed, Vol I & 2, Charles Fayette Taylor, MIT Press, 1999.
3. Diesel Engine Technology: Fundamentals, Service, Repair, James P. Mack, Jason A. Daniels, Mark A. Dehart and Andrew Norman, 9th Edition, 2020, Goodheart-Willcox Publications

Course Name- *Marine Gas Turbines*

Course Code- *ME 645*

Course Outcome:

- CO1** Students will be able to **analyse, apply & explain** basic working of marine gas turbines in terms of its thermodynamic and mechanical behaviour
- CO2** Students will be able to **analyse, apply & explain** aerodynamic & mechanical design & performance characteristics of gas turbines and compressors
- CO3** Students will be able to **analyse & explain** performance, design requirements and emissions of Marine gas turbine combustors
- CO4** Students will be able to analyse and apply principles of matching in single and dual shaft gas turbines

Syllabus Details	Outcome
Unit I	CO1
Unit II & III	CO2
Unit IV	CO3
Unit V	CO4

Unit I: Gas Turbine theory: Gas Turbine Types and application; Cycle Analysis & Performance; Cycle with Regeneration and Reheat factors; Single and Twin shaft engine with FPT; Gas Turbine design procedure; Use of IGVs & VGVs.

Unit II: Axial Flow Compressors: Compressor stage design and Performance; Factors affecting pressure ratio: tip speed, axial velocity, diffusion factor, work done factor; **Case Studies:** Design process, Blade design; Stage performance, off-design performance, Axial flow compressor characteristics.

Unit III: Marine GT Combustors: Types of combustion systems, Factors affecting combustor performance, Combustion process, Combustion chamber performance, Gas turbine emissions, Practical problems

Unit IV: Axial flow Turbine: Turbine stage design and Performance; Vortex theory; Case study: Choice of Blade shapes, pitch and chord; Stage performance; Turbine performance characteristics; Blade cooling methods.

Unit V: Performance of Gas turbine: Compressor turbine Matching principle: Single shaft gas turbine; Gas generator Equilibrium running diagram; Matching of gas generator and free turbine; Methods of displacing equilibrium running line. Design & off- design point performance, Transient performance of gas turbines: single shaft and free turbine.

Texts Books/References

1. Gas Turbine Theory, 5th Ed, Cohen, Rogers & Sarvamuttu, John Wiley & Sons, 2001.
2. Fluid Mechanics and Thermodynamics of Tubomachinery, SL Dixon, 6th Ed, Elsevier, 2010.
3. Gas Turbine 2nd Ed, V Ganeshan, Tata McGraw Hill, 2010.
4. Fundamentals of Gas Turbines, 2nd Ed, Bathie WW, John Wiley, 2003.
5. The Design of Hi-efficiency Turbomachinery and Gas Turbine, DG Wilson & T Korakianitis, MIT Press, 2002.

Course Name- Nuclear Reactor Engineering

Course Code- ME 646

Course Outcome:

- CO1** Students will **understand &** be able to **apply** basic knowledge of nuclear physics
- CO2** Students will be able to demonstrate **understanding** on safety aspects related to functioning of a nuclear reactor
- CO3** Students will be able to **analyse, apply and explain** thermal and hydraulic design aspects of nuclear reactor systems
- CO4** Students will **understand &** be able to **explain** basics of control and instrumentation of an nuclear reactor

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO3
Unit III & IV	CO2
Unit V	CO4

Unit I: Nuclear Reactor Physics: Introduction to nuclear physics: nuclear fission, nuclear reactions and radiations. Reactor analysis, reactor kinetics and control,

Unit II: Nuclear Reactor Engineering: Thermal & hydraulic aspects of reactor design, energy removal. Core and Fuel design. Reactor process system, reactor fuel design. Design aspects of major reactor components, material selection, shielding design. Overview of nuclear fuel cycle. Different reactor systems,

Unit III: Nuclear Reactor Safety: Overview of nuclear safety philosophy, defense in depth principle, different safety systems,

Unit IV: Health Safety: Effects of different types of radiation, dosage, radiation monitoring.

Unit V: Nuclear Reactor Control & Instrumentation: General features of reactor control, control in reactor operation. Basics of reactor instrumentation, instrumentation range and wide range of detectors used. Visit to BARC Mumbai for one day.

Texts Books

1. Nuclear Reactor Engineering: Reactor Design Basics, Volume – 1, Samuel Glasstone and Alexander Sesonske, CBS Publishers and Distributors, 2002.
2. Nuclear Reactor Engineering: Reactor systems engineering, Volume - 2, Samuel Glasstone and Alexander Sesonske, CBS Publishers and Distributors, 2002.
3. Introduction to Nuclear Engineering, John R. Lamarsh and Anthony J. Baratta. Prentice Hall; 3rd editions, 2001.

Course Name- *Convective Heat Transfer*

Course Code- *ME 654*

Course Outcome:

- CO1** Students will be able to **explain, analyze & apply** basic convection principles
- CO2** Students will be able to **analyze & apply** internal & external forced convection concepts to real life problems.
- CO3** Students will be able to **apply & explain** basic concepts of natural and mixed convection to basic flow configurations

Syllabus Details	Outcome
Unit I	CO1
Unit II & III	CO2
Unit IV	CO3

Unit I: Basic concepts of convection: Energy Equation, Generalized approach to energy equations, Dimensionless Groups, Velocity and thermal Boundary layer, Equation for thermal boundary layer: Scaling analysis of steady flow over flat plate, Significance of Prandtl number

Unit II: External Laminar Forced convection: Thermal boundary layer equation (Pohlhausen solution), Approximate solution for flat plate boundary layer problem, Flow past cylinder: Strouhal number, Average Nusselt number

Unit III: Internal Laminar Forced convection: Thermally fully-developed flow, Energy balance, Constant wall temperature case, constant wall heat flux case, Hydrodynamically & Thermally developed flow with constant wall heat flux, Graetz problem: Hydrodynamically developed & Thermally developing flow with constant wall heat flux

Unit IV: Natural/Free and Mixed convection: Free convection over vertical flat plate, Grashof number, conditions for free/forced/mixed convection, free convection for vertical cylinder, Rayleigh-Benard convection, Introduction to turbulent heat transfer.

Practice: Solve thermal boundary layer over flat plate using Matlab/C/python code

Text Books:

- I. Introduction to Convective Heat Transfer Analysis by Patrick H. Oosthuizen and David Layor (McGraw-Hill)
- II. Convective Heat and Mass Transfer by Kays, Crawford and Weigand (4th Edition, McGraw-Hill)
- III. Convective Heat Transfer by L C Burmeister (Wiley)

Reference Books:

- I. Convective Heat Transfer by Adrian Bejan (4th Edition Wiley)
- II. Boundary Layer Theory by H Sctlichting (McGraw-Hill)
- III. Heat and Mass transfer by Eckert ERG and Drake RM (Translated by J P Gross, McGraw-Hill)
- IV. Convective Heat Transfer: Solved Problems by Michel Favre-Marinet and Sedat Tardu (Wiley)

Course Name- *Marine Hydrodynamics*

Course Code- *ME 657*

Course Outcome:

- CO1** Understand and review of Ideal and viscous incompressible fluid; Kinematics of fluid; Lagrangian and Eulerian methods of description, velocity, acceleration, streamlines, pathlines, vorticity
- CO2** Understand the basic Two dimensional motion - velocity potential, stream function, Sources, sinks, dipoles; Flow past a circular cylinder with and without circulation; Blasius Theorem
- CO3** Understand The vortex system-circular vortex, two dimensional sources and vortex distributions, vortex sheets; Lifting Surfaces, Aerofoil theory; Velocity and pressure distribution on aerofoils; Viscous fluids- Navier-Stokes equations, Laminar flow, Poiseuille flow, Couette flow
- CO4** Understand Gravity waves- Airy's wave; Free surface condition; Velocity potential- Dispersion relation; Surface tension effects; Orbital motion; Group velocity and its dynamical significance; Wave energy

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO2
Unit III	CO3
Unit IV	CO4

Unit I: Ideal and viscous incompressible fluid; Kinematics of fluid; Lagrangian and Eulerian methods of description, velocity, acceleration, streamlines, pathlines, vorticity; Equation of continuity; Euler's Equations of motion; Bernoulli's equation and its application,

Unit II: Two dimensional motion - velocity potential, stream function, Sources, sinks, dipoles; Flow past a circular cylinder with and without circulation; Blasius Theorem; Problems on the motion of perfect fluids - steady translation of a cylinder in an infinite fluid medium, unsteady translation; Added mass of cylinders; Spheres;

Unit III: The vortex system-circular vortex, two dimensional sources and vortex distributions, vortex sheets; Lifting Surfaces, Aerofoil theory; Velocity and pressure distribution on aerofoils; Viscous fluids-Navier-Stokes equations, Laminar flow, Poiseuille flow, Couette flow, flow through a pipe; Boundary layer Theory-Reynolds Number; Boundary layer along a flat plate; Blasius solution; Separation, Von Karman momentum integral method;

Unit IV: Introduction to Turbulence; Gravity waves- Airy's wave; Free surface condition; Velocity potential- Dispersion relation; Surface tension effects; Orbital motion; Group velocity and its dynamical significance; Wave energy; Standing waves; Loops and nodes, Wave forces and Morison's equation, Long waves and waves in a canal; Tides.

TextBooks:

1. Lamb, H. (1995) Hydrodynamics, 6th Edition, Cambridge University Press, USA
2. Newman, Nick, (1977) "Marine Hydrodynamics" MIT Press.

References:

1. Frank, White (2005) Viscous Fluid Flow, McGraw-Hill Education; 3RD edition.
2. Milne-Thomson, L. M. (1996) Theoretical Hydrodynamics, Dover Publications, Inc. New York. Introduction to Fluid Mechanics
3. Dean, R. G. & Dalrymple, R. A. (2001) "Water Wave Mechanics for Engineers and Scientists" Allied Publishers Limited, New Delhi (Reprint of World Scientific, Singapore).

Course Name: *Heat Exchanger Design*

Course Code: *ME 660*

Course Outcome:

- CO1** Understand the basics of Heat exchangers, its classification of different applications. Introduction to Thermal and hydraulic aspects, pressure drop and heat transfer, sizing and rating, LMTD and NTU method etc.
- CO2** Understand role of Biot number and its significance in Fin design, lumped parameter analysis, effectiveness, efficiency and thermal resistance of fins. Understand different types

of heat exchangers. Evaluate Fouling and corrosion and its effect on heat transfer and pressure drop and calculations for shell and tube heat exchanger.

- CO3** Analyze the different components and their functions in connection Heat Pipe and Phase change heat exchangers and apply the understanding to the design of future systems.
- CO4** Understand and evaluate the requirement of Heat Exchanger packaging and testing and proposing solution to the existing problems persisting in current inventory of combat vehicles.

Unit I: Introduction to Heat Exchangers: Introduction, Application of Heat exchangers, Classification of heat exchangers, Types of heat exchangers, common terminologies, Introduction to Thermal and hydraulic aspects, pressure drop and heat transfer, sizing and rating, LMTD and NTU method

Unit II: Fin Design: Biot number and its significance, Applicability of Lumped parameter analysis, Fins and its design, Effectiveness and efficiency, Heat transfer from fin array, Thermal resistance concept

Unit III: Heat Exchanger Design: Shell and Tube Heat Exchangers, Fin tube heat exchanger, Plate Fin Heat Exchangers (PFHE), Direct contact heat exchangers, Regenerators and Recuperator, types of regenerators, construction, application, Theory of Regenerator

Unit IV: Fouling and corrosion: Effect of fouling on heat transfer and pressure drop, Fouling mechanisms, single phase liquid side, single phase gas side, Prevention of fouling, Types of corrosion, corrosion control, advantages and disadvantages of water as a medium in heat exchangers

Unit V: Advanced topics: Heat Pipe and Phase change heat exchanger: Heat pipes, construction, working principle, application, and analysis. Special heat pipes, Phase change heat transfer, Phase change heat-exchangers (Evaporators and Condensers)

Unit VI: Heat Exchanger packaging and testing: Heat Exchanger packaging, Air elimination unit, Air blower/ fan power requirements, Safety valves, Heat Exchanger testing: Steady state and dynamic methods

Text Books:

1. Fundamentals of Heat Exchanger Design by Ramesh K. Shah & Dusan P. Sekulic (John Wiley & Sons)
2. Heat Exchangers: Selection, Rating, and Thermal Design by Sadik Kakaç, Hongtan Liu, Anchasa Pramuanjaroenkij (CRC Press)
3. Heat Exchanger Design by Arthur P. Fraas, Fraas (Wiley)

Reference Books:

1. Heat Exchanger design handbook by T. Kuppan
2. Compact Heat Exchangers by William M. Kays and A.L. London, (Krieger Publishing Company)
3. Fundamentals of heat transfer - Frank P. Incropera, David P. DeWitt

Course Name- *Computational Fluid-Structure Interaction and its Applications*

Course Code- *ME 661*

Course Outcome:

- CO1** Understand the real-life problems of Fluid-Structure Interactions (FSI) and fundamental of governing equations and boundary conditions. Learn Fundamentals of Computational Fluid Dynamics (CFD) using Finite Volume and Finite Element techniques.
- CO2** Understand and evaluate Fluid-structure Coupling and Interface handling: Fluid-structure coupling algorithm-Partitioned coupling schemes, Arbitrary Euler-Lagrange (ALE).
- CO3** Analyze the different modules and their functions available in AUTODYN software for simulation of coupled Fluid-Structure Interaction problems.
- CO4** Understand and evaluate different real-life problems through simulation using ANSYS AUTODYN software.

Unit I: Introduction: Fluid-Structure Interactions (FSI), Real world examples of FSI, Models of the Flow, Finite Control Volume, Infinitesimal Fluid Element, The Substantial Derivative, Physical meaning of Divergence of the Velocity, Continuity, Momentum and Energy Equations, Equations for Inviscid Flow (the Euler Equations), Comments on governing equations, Physical Boundary Conditions.

Unit II: Fundamentals of Computational Fluid Dynamics (CFD): Basic aspects of Discretization, Introduction of Taylor series, Finite Difference and Finite Volume formulation of steady/transient one-dimensional conduction equation, Consistency, Convergence and Stability, Temporal Discretisation Explicit Schemes Implicit Schemes

Unit-III: Fundamentals of Finite Element Method (FEM): Finite Element Formulation Starting from Governing Differential Equations, Weighted Residual Method, The General Weighted Residual (WR) Statement, Weak (Variational) Form of the Weighted Residual Statement, One-dimensional Finite Element Analysis, One-dimensional Heat Transfer

Unit-IV: Fluid-structure Coupling and Interface handling: Fluid-structure coupling algorithm-Partitioned coupling schemes, Arbitrary Euler-Lagrange (ALE) preliminaries, Kinematics, Fluid equations on a moving domain, Structure equations, Strong vs weak coupling

Unit-V: Introduction to ANSYS AUTODYN: Introduction to Autodyn, Graphical User Interface (GUI), Basic features of Autodyn, Explicit Dynamics Products, Lagrange Solvers, Euler Solvers, ALE (Arbitrary Lagrange-Euler) Solver, Coupling, Contact and Erosion, Using Autodyn in Workbench and as Standalone, Multi-material Euler Solver, Euler-Blast solver, Rigid, Fully and Weak and Polygon coupling, Introduction of material models

Unit-VI: ANSYS AUTODYN Exercise Problems

1. Shaped Charge Impact,
2. Effect of blast in Urban area,
3. Mine blast under a vehicle,
4. Analysis of remotely operated self-actuated blast valve,
5. Underwater shock loading of a ship,
6. Penetration of 2000 lbs GP bomb in composite structure,
7. Kinetic Energy Projectile Impact on Reinforced Concrete

Text books/References:

1. **Computational Fluid Dynamics the Basics with Applications, Jr., John D. Anderson, ISBN-13: 9780071132107, McGraw Hill Education**
2. Textbook of Finite Element Analysis, P. Seshu, PHI Learning Pvt. Ltd, ISBN: 9788120323155, 9788120323155
3. Computational Fluid-Structure Interaction: Methods and Applications, Yuri Bazilevs, Kenji Takizawa, Tayfun E. Tezduyar, ISBN: 978-0-470-97877-1

4. Arbitrary Lagrangian Eulerian and Fluid-Structure Interaction-eBook, M'hamed Souli, ISBN-13: 9781118618684, Wiley
5. ANSYS AUTODYN User's Manual, ANSYS Inc.

Course Name- *Combat Vehicle Engineering Lab*

Course Code- *ME 662*

Course Outcome:

- CO1** Visualize and understand the basics of Combat vehicle structure, Systems of Combat Vehicle, Hull, Track, Suspension system, Critical dimensions and Basic structure of various types of A-Class Vehicles.
- CO2** Visualize and understand the off road and amphibious vehicle design, Power packs of A-Class Vehicles, Transmission, Steering and gear system, Hydrokinetic and Hydro static Drives,
- CO3** Visualize and understand the design of superstructure, the Turret, Ammunition Rack, Study the different components and their functions and apply the understanding to the design of futuristic combat vehicles.
- CO4** Visualize and understand the design of Gun Barrel, Different caliber of guns, Recoil, Muzzle Brake, Sighting System, Gun and Fire Control System, human response to vibrations of combat vehicles

Unit -I: Understanding of Basic structure, Critical Dimensions and Suspension System of Tank

1. Live demonstration of Combat Vehicle tank T-72
2. Live demonstration different Types of A-Vehicles (Tanks, ICV's etc.).
3. Structure of Combat Vehicle Chassis.
4. Basic Structure of Combat Vehicle Hull, Track, Idler, drive sprocket, Boggie Wheel, turret, Suspension system etc.
5. Explaining critical dimensions of T-72 during live demonstration.
6. Armour protection system

Unit -II: Understanding of Power Packs and Transmission System of Tank

- I. Live demonstration of amphibious characteristics of A-Class vehicles.
- II. Power plant used in combat vehicle (UTD -20 used in ICV BMP Variants, V-46-6 used in Tank T-72 Variants, Cummins engine, brief on working model) Gun Barrel and breech block
- III. Auxilliary Power systems
- IV. Components of Power pack such as Fuel System, Cooling system, Lubrication System, Air induction and filtration system,
- V. Driving control system, Steering system, Brake system, Pneumatic system etc.
- VI. Side gear box-Left and Right side of tank T-72 (Brief on dismantle condition of gear box).
- VII. Basic epicyclic gear train brief on working model.

Unit -III: Understanding of Superstructure and its components

- I. Super Structure of Combat Vehicle: Turret, Gun Barrel and breech block etc.
- II. Live demonstration of Gun control system, Sighting system, Ammunition automatic loading System etc. Electrical System, Fire control system.
- III. Main Gun and Co-Axial gun system (Smooth bore and Rifeled Bore)
- IV. Crew Compartments: Spaces within the turret for the crew, including the commander, gunner and loader.
- V. NBC system
- VI. Fire power impact on different type of ammunitions

Unit -IV: Understanding ergonomics, human response, design of space for crew members in turret and hull

- I. Understanding human response to vibrations inside combat vehicles
- II. Live demonstration of Crew compartment within turret and hull
- III. Air-conditioning/ ventilation/ thermal management system for crew comfort
- IV. Understanding the requirement of an active protection system in comparison to existing protection systems
- V. Understanding the differences between existing combat vehicles and FRCV, FICV, Light tank etc.

Course Name- *Armaments Engineering Lab*

Course Code- *ME 663*

Course Outcome:

- CO1** Visualize and understand the working of Armaments used by Indian Army
CO2 Visualize and understand the working of Armaments used by Indian Air Force
CO3 Visualize and understand the working of Armaments used by Indian Navy.

Unit I: Armaments used by Indian Army

1. Intro of small arms system.
2. Working principal on small arm system
3. Live Demonstration of different types of guns
4. Type of small arms.
5. Brief on components of small arms (AK-47, Insas, LMG, 7.62mm MMG, Mortar, RPG, RCL).
6. Type of Artillary guns
 - a. Air Defence (AD) Guns.
 - b. Field Defence (FD) Guns.
7. Type of ammunition
 - a. Tank Ammunition
 - b. Artillary ammunition.
 - c. Small Arms ammunition.
 - d. Mortar ammunition.
8. Type of mines
 - a. Anti person
 - b. Anti tank.

Unit II: Armaments used by Indian Air Force

1. Intro on Combat Fighters in India.
2. Demo of different types of bombs.
3. Missile air to air Akash model.
4. Prithvi missile war head.
5. Bramhos missile model.
6. Cluster bomb model.
7. SAM missile.
8. NAG missile model.
9. 50-pound bomb model.
10. Tejas fighter model.
11. MARUT fighter live model.
12. SU fighter live model.
13. Fighter jet seat ejection live demo.
14. Fighter jet engine.
15. Gun 30mm use in combat fighter jet.

Unit III: Armaments used by Indian Navy

1. Intro on Naval Armament system.
2. Torpedo.
3. Frigate mounted gun system
4. Naval use ammunition
5. Anti-submarine missile and mines.

Course Name- *Advanced Thermodynamics*

Course Code- *ME 664*

Course Outcome:

- CO1** Application of basic concepts of 1st law to different thermodynamic cycles for closed and open systems
- CO2** Analyze and apply concepts of irreversibility and exergy to different power cycles
- CO3** Understand and apply general thermodynamic relations
- CO4** Understand and apply 1st and 2nd law principles to combustion processes

Syllabus Details	Outcome
Unit I	CO1
Unit II	CO2
Unit III	CO3
Unit IV	CO4

Unit I: Basic concepts: Fundamentals of heat and work, Thermodynamic behavior of real gases, First Law Analysis of Closed Systems with applications, First law applied to open systems with Applications: Otto, Diesel, Brayton, Stirling cycle Analysis. (10 Hrs)

Unit II: Second law Analysis: Entropy, Second Law Analysis of Closed Systems with applications, Second Law Analysis of Open Systems with Applications, Irreversibility and availability, Exergy balance equation. (10 Hrs)

Unit III: Thermodynamic Relations: Clapeyron Equations, Maxwell Relations: Gibbs and Helmholtz functions, General thermodynamic relations for internal energy, enthalpy and entropy. (10 Hrs)

Unit IV: Thermodynamics of Chemical reactions: Introduction, theoretical combustion process, actual combustion process, enthalpy of formation, enthalpy of combustion and heating values, adiabatic flame temperature, Third Law of Thermodynamics and absolute Entropy of a substance, Second law Analysis of Reacting Systems. (15 Hrs)

Text Books:

1. Fundamentals of Thermodynamics, Richard E. Sonntag, Claus Borgnakke and Gordon J. Van Wylen, Sixth Edition, 2022, Wiley Publications
2. Engineering Thermodynamics, P K Nag, 6th Edition, 2017, McGraw Hill Education
3. Thermodynamics: An Engineering Approach (SIE), Yunus A Cengel; Michael A Boles, 9th Edition, 2019, McGraw Hill

Reference Books:

1. Fundamentals of Thermodynamics, 10ed (An Indian Adaptation), Claus Borgnakke ; Richard E. Sonntag; Souvik Bhattacharyya; Manoj Kumar Soni, 10th Edition, 2022, Wiley Publications
2. Principles of Engineering Thermodynamics, Moran, Shapiro, Boettner, Bailey, 8th Edition, 2015, Wiley Publications
3. Thermodynamics, Jack Holman, 4th Edition, 1988, McGraw-Hill Education
4. The Dynamics of Heat: A Unified Approach to Thermodynamics and Heat Transfer, Hans U. Fuchs, 2nd 2010, Springer-Verlag New York Inc. Publications
5. Thermodynamic and Transport Properties of Fluids, G. F. C. Rogers & Y. R. Mayhew, 5th Edition, 2021, Wiley-Blackwell

Course Name- *Lab in Mechanical Engineering*

Course Code- *ME 665L*

Course Outcomes (COs)

- CO1** Understand the basics of steady state heat transfer and determine heat transfer temperature difference
- CO2** Determination of the heat transfer rate and the exchanger effectiveness
- CO3** Measure the Temperature of Furnace by using the thermal Image Camera
- CO4** Compute Frequency response function of spring mass damper system

List of Experiments:

- Steady State Determination of heat transfer temperature difference and surface heat transfer coefficient for a single tube in a transversely flowing air stream.
 - Determination of the Relationship between Nusselt and Reynolds Number for the forward stagnation point on a cylinder in cross flow using the Direct Heat Transfer Cylinder.
 - Determination of the heat transfer rate and the exchanger effectiveness.
 - Measure the distribution of Total pressure and Static Pressure along the duct and to compare these with the predictions of Bernoulli's equation
 - Measure the Temperature of Furnace by using the thermal Image Camera.
1. Undamped free vibration test of Single degree of freedom on Vibration Fundamental Trainer (VFT)

2. Frequency response function of spring mass damper system for various damping mediums: air, water, and oil.
3. Beam lateral experiment.

Text Books/References:

1. “Introduction to Fluid Mechanics” by R.W. Fox and A.T. McDonald, McGraw Hill
2. “Fluid Mechanics” by Kundu & Cohen, Elsevier Publications
4. Introductory Course on Theory and Practice of Mechanical Vibrations, J.S. Rao, K. Gupta, Revised second edition, New Age International Publishers
5. Theory of Vibration with Applications, William T. Thomson, Marie Dillon Dahleh, Pearson Low Price Edition.
6. Mechanical Vibrations, J.B.K. Das & P.L.S. Murthy, Sapna book house.

Course Name- M. Tech. Dissertation Phase– I

Course Code- ME 651

Course Name- M. Tech. Dissertation Phase– II

Course Code- ME 652

Course Name- Research Methodology and IPR

Course Code- PGC 01

Course Outcomes (COs):

CO1	Understanding the fundamentals of research and its methodology
CO2	Choose the appropriate research design and develop appropriate research hypothesis for a research project
CO3	Knowledge of manuscript preparation, patents and Intellectual property
CO4	Technology transfer and application of IPR in various domains

Course Contents:

- Unit I:** Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations
- Unit II:** Effective literature studies approaches, analysis Plagiarism, Research ethics,
- Unit III:** Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee
- Unit IV:** Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation,

patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Unit V: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications

Unit VI: New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

References Textbooks:

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students"
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
3. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step-by-Step Guide for beginners"
4. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.
5. Mayall, "Industrial Design", McGraw Hill, 1992.
6. Niebel, "Product Design", McGraw Hill, 1974.
7. Asimov, "Introduction to Design", Prentice Hall, 1962.
8. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.
9. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Course Name: Professional Development & Employability Skills (PDES)

Course Code: PGC 602

Course Outcomes (COs):

- CO1** Prepare for placement with excellent Communication Skills, Interview Skills, Body Language and Resume Writing Skills
- CO2** Develop problem-solving skills, Decision Making and Conflict Management
- CO3** Develop interpersonal skills and be an effective goal-oriented team player
- CO4** To re-engineer attitude and understand its influence on behaviour

Course Contents:

Unit I

Introduction & Communication Skills: Importance of Communication in Professional Life, Verbal and Non-Verbal Communication, Active Listening, Principles of Effective Communication

Unit II

Body Language & Public Speaking: Understanding Body Language Cues, Projecting Confidence and Authority, Overcoming Stage Fright, Structuring a Speech, Delivery Techniques

Unit III

Time Management & Team (Leadership) Development: Time Management Techniques (Prioritization, Scheduling), Team Dynamics and Roles, Leadership Styles, Conflict Resolution within Teams, Goal Setting.

Unit IV

Decision Making & Conflict Management: Decision-Making Process, Problem-Solving Techniques, Conflict Resolution Strategies, Negotiation Skills, Handling difficult people.

Unit V

Self-Assessment & Emotional Intelligence: Importance of Self-Awareness, Identifying Strengths and Weaknesses, Emotional Intelligence Components (Self-Awareness, Self-Regulation, Empathy, Social Skills), Managing Emotions in Professional Settings

Unit VI

Interview Skills & Resume Writing: Types of Interviews (Technical, Behavioural, HR), Preparing for Interviews, Answering Common Interview Questions, Resume and Cover Letter Writing, Creating a Professional LinkedIn Profile

Text Books:

1. Goldbort R *Writing for Science*, Yale University Press (available on Google books): 2006
2. Day R: *How to write and Publish a Scientific Paper*, Cambridge University Press :2006
3. Adrian Wallwork, *English for Writing Research Papers*, Springer New York, 2011

Chakroborty, S.K. “Values and Ethics for organizations Theory and practice”, Oxford University Press, New Delhi

Reference Books:

1. S.C. Parja & Vikram Kate. *Writing and Publishing a Scientific Research Paper*. Springer: 2017.
 2. “Abhyaspustakam” – Dr. Vishwas, Samskrita-Bharti Publication, New Delhi
 3. Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, *Compare*, 31 (2):245-261.
- Agrawal M (2004) Curricular reform in schools: The importance of evaluation, *Journal of Curriculum Studies*, 36 (3): 361-379.

*Department of Computer
Science & Engineering*

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING (CSE)

In the vibrant landscape of technological digital advancement, the Department of Computer Science and Engineering was founded in 1987, with the first MTech course offered in 2009; while AM has been integral part of our institute's history since its inception. We stand on the shoulders of this rich legacy as to strengthen and apply modern digitization, as a step into a future defined by innovation, critical thinking, and scientific excellence.

As Department of Computer Science and Engineering, we offer a tapestry of TWO Post-Graduation academic programs and research ventures, a testament to our commitment to diversity and multidisciplinary. From M.Tech., to Ph.D programs are tailored for scientists of R&D organizations, officers of Tri- Services, GATE-Qualified candidates, & self-financed scholars, our offerings are diverse as the ever-evolving world of technology. Among our flagship M.Tech. programs are CSE (Artificial Intelligence) and Cyber Security.

Our dynamic community comprises approximately 160 post-graduate students per year; fueled by the boundless curiosity of successful 21 Ph.D. completions. They thrive an ecosystem that fosters creativity and explorations, where the cutting-edge laboratories, state-of-art equipment, and a stellar faculty beacon them into the world of tomorrow's technological needs. Our 13 faculty members luminaries in fields ranging from Cyber Security, and Artificial Intelligence to Ethical hacking, Cryptography, Computer Vision, Natural Language Processing, and Generative Adversarial Networks.

Research at CSE Department isn't just a buzzword; it's our heartbeat. We are on the forefronts of cutting-edge research, impart trainings, actively managing funded projects and ahead in revenue generations. The department has received accolades for recognitions via patents & publications; in various national level hackathons; national & international conferences & seminars, Sports & Cultural events. CSE Department is the driving force behind the Data Centre activities, facilitating internet access, email service, and web hosting for DIAT.

CSE Department's dedication extends beyond the walls of DIAT. We are championing ATMA-NIRBHAR BHARAT INDIA@75 with PAN-INDIA Certification Courses in Artificial Intelligence & Cyber Security. The customized programs for Tri-Services and other national organizations underscore our commitment to empowerment and growth to build self-reliant nation. With resounding emphasis on research, interdisciplinary collaborations, and a global outlook, CSE Department stands tall as the vanguard of education, charting the course for a brighter future, to build self-reliant and sustainable nation. The aspiring candidates are welcome to the CSE Department where innovation know no bounds!

To be a Center of Excellence of international repute for Education, Training and research in Advanced Technologies with a view to strengthen national security and self-reliance.

Institute Mission

To evolve as an Innovative Unique Research University to develop indigenous contemporary Defence related technologies in Navigation Systems, Wireless Sensors, Efficient Propulsion Systems, and Weapon Systems for DRDO and Defence Services, provide technological solutions to the Services optimize combat battlefield effectiveness and above all produce qualified quality manpower which can truly become an instrument for building a strong indigenous technology base in the context of creating a performing Defence Industrial Base in India.

Department Vision

To be a Center of Excellence of International repute to provide high-quality education, research, and training in the area of Cyber Security (CS) and Artificial Intelligence (AI) to promote innovation and entrepreneurship skills among the students with a view to strengthen national security and self-reliance.

Department Mission

M1	To build strong education, teaching and research environment in the field of Cyber Security (CS) and Artificial Intelligence (AI) to meet requirements from Defence, specially related to national security.
M2	To strive for continuous learning, innovation, entrepreneurship and quality research culture amongst the student community through effective government, industry & academia collaboration.
M3	To encourage ethics, team work and technological leadership skills among students to solve complex engineering problems collaboratively by imparting strong theoretical foundation complemented with extensive practical training.
M4	Engage with industry, government, DRDO, Tri-services and PSUs to transfer knowledge

M.Tech in Cyber Security

Introduction: Communication networks and information systems have become an essential factor in economic, social development and almost in every facet of our daily lives. Information systems are vulnerable to one or more types of cyber-attacks. The security of communication networks and information systems and their availability in particular, is therefore of increasing concern. In general, cyber security threats are increasing rapidly, the incidents range from defaced websites to theft of large volumes of intellectual property and money, to even Internet crimes. Cyber security is now a

prominent field of study. Professionals who are trained in this field are highly regarded and contribute to strengthening the social, political and financial fabric of modern society.

The domain of cyber security refers to the collection of tools, policies, security concepts, guidelines, risk management approaches, actions, training, best practices, assurance and technologies that can be used to protect the cyber environment, organization and user's assets. To survive in an Information Centric Warfare scenario, the tools and techniques of cyber security will provide mechanisms to safeguard the critical systems against related threats & attacks.

Eligibility: Full-time B.E./B.Tech. in Computer Science/ Electronics/ Electrical/ Electronics & Communications/ Telecommunications/ Information Technology/ Cyber Security or equivalent discipline or Full-time M.Sc. in Computer Science/ Mathematics or equivalent discipline with a valid GATE score in- CS, DA, EC, EE, MA, ST, BM, IN. [Computer Science & Information Technology (CS), Data Science & Artificial Intelligence (DA), Electronics & Communication Engineering (EC), Electrical Engineering (EE), Mathematics (MA), Statistics (ST), Biomedical Engineering (BM), Instrumentation Engineering (IN).]

Organization: The program curriculum has been designed considering the Cyber Security requirements of Industry and Defence Research and Development. It is designed and reviewed by a panel of experts from Academia, DRDO labs, IDS, R&D Industry, and Alumni. The course work includes Core and Elective courses related to the Cyber Security domain.

Each subject of 3 credits is delivered by subject experts over the duration of 16 weeks approximately. It consists of 3 hrs. of classroom interaction per week. The evaluations follow a continuous assessment process that includes – 2 intermediate evaluation exams (20 Marks each), an internal assessment (10 Marks), and a final examination (50 Marks). The separate lab course focuses on practical exposure to the Cyber Security tools and techniques in the form of mini-projects and lab assignments and evaluated as per new PGC guidelines. The 3rd and 4th semesters have a major component of M.Tech. project dissertation of 20 credits each, where the students work under close supervision and guidance of their project guide. The students present their work at the end of 3rd and 4th semester. The M.Tech. thesis is submitted and evaluated by the panel of expert examiners at the end of the 4th semester.

For 2-year M.Tech.: The M.Tech. programmes will comprise of course work in the first year and research work in the second year. However, the students shall be allowed to opt for (i) only course work in the third and fourth semester or (ii) course work in the third semester and research in the fourth semester or (iii) only research in the third and fourth

semester subject to meeting the credit requirements. For I-year M.Tech, Students entering I-year PG after a 4-year UG programme with honours with research and NEP in the same discipline can choose to do (i) only coursework or (ii) research or (iii) coursework and research meeting the credit requirements of at least 40 credits in a year. For a 2-year M.Tech, students may exit at the end of first year with an additional 3 credits course (CSE allied). Such students should be awarded the degrees as per the current NEP norms (M.Voc{Engg}) exiting at level 6.5 for M. Tech. enrolled students.

Program Educational Objectives (PEOs)

- PEO1** The M.Tech. courses of CSE Department aims at developing skilled Human Resources in the field of Digitization by providing different specializations in CS and AI; catering to the emerging multidisciplinary problem-solving needs of defense, civil, and DRDO sectors.
- PEO2** M.Tech. in Cyber Security (CS) programme aims at developing skilled Human Resources in the field of Cyber Security with a thrust on solving defence and society-related problems. The present program is conceived to understand, assimilate & use advanced technologies such as Network security, Cryptography, Ethical Hacking, Digital Forensic, Malware Analysis, Information Security Management and Trusted Computing techniques. After completing this course, students are expected to understand and practice the essential CS concepts along with developing secure systems.
- PEO3** M.Tech. Computer Science and Engineering with specialization in Artificial Intelligence programme aims at developing skilled Human Resources in the field of AI with a thrust on solving defence and society related problems. The present programme is conceived to understand, assimilate & apply the advanced technologies such as deep learning, robotics, machine learning, computer vision, video surveillance, text analytics, speech analytics etc. After completing this course, students are expected to understand and practice the essential AI concepts along with developing AI based systems to solve society/defence related problems, carry out research and innovation.

Program Outcomes (PO)

- PO1** The M.Tech. in Cyber Security & M.Tech in CSE with specialization in AI aim at developing an ability in students to independently carry out research /investigation and development work to solve practical problems.
- PO2** The M.Tech. Cyber Security & Computer Science and Engineering aim at developing an ability in students to write and present a substantial technical report/document.
- PO3** The M.Tech. students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

Program Specific Outcomes (PSO)

- PSO1** The M.Tech. Computer Science and Engineering aims at developing skilled knowledgeable Human task force in the field of Cyber Security, catering the needs of defence, social and DRDO requirements
- PSO2** The M.Tech. Computer Science and Engineering aims at developing skilled knowledgeable Human task force in the field of Artificial Intelligence, catering the needs of defence, social and DRDO requirements.

MTech (Cyber Security) Program Structure:

PSC: Program Specific Core PSL: Program Specific Lab PE: Professional Elective

SEMESTER I

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-1	CS-601	Data Security & Privacy	3	0	3
2	PSC-2	CS-602	Machine Learning for Cyber Security	3	0	3

3	PSC-3	CS-603	Applied Cryptography	3	0	3
4	PSC-4	CS-604	Advanced System Security	3	0	3
5	PE-I		Elective – I (From Department)	3	0	3
6	PSL-I	CS-606L	Cyber Security Skill Development Lab	0	3/6	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total	17	3	20

SEMESTER II

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-5	CS-611	Digital Forensics	3	0	3
2	PSC-6	CS-612	Reverse Engineering & Malware Analysis	3	0	3
3	PE-II		Elective – II (From Department)	3	0	3
4	PE-III		Elective – III (From Department)	3	0	3
5	PE-IV		Elective – IV	3	0	3
6	PSL-II	CS-607L	Cyber Security Advanced Skill Development Lab	0	3/6	3
7	PGC	PGC-602	Communication Skills & Personality Development	2	0	2
			Total	17	3	20

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	CS-651	M.Tech. Dissertation and Seminar Phase-I	40		20
		Total	40		20

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	CS-652	M.Tech. Dissertation and Seminar Phase-II	40		20
		Total	40		20

List of Subjects (Applicable for Sem - II):

Sr.No.	Course Code	Course
1.	PGC-602	English for Research Paper Writing
2.		Disaster Management
3.		Sanskrit for Technical Knowledge
4.		Value Education
5.		Constitution of India
6.		Pedagogy Studies
7.		Stress Management by Yoga
8.		Personality Development through Life Enlightenment Skills

List of Electives/Open Electives (Applicable for Sem - I):

Sr. No.	Course Code	Course
1.	CE-606A	Software Engineering & System Modelling
2.	CS-605	Network and Cloud Security
3.	CS-613	Security Standards & Penetration Testing
4.	CE- 613	Large Language Models
5.	CE-613A	Speech and Language Processing
6.	CE-71A	Reinforcement Learning
7.	CE-605	Mathematics for ML
8.	MOOC	Any relevant MOOC course for 3 credits upon

List of Electives/Open Electives (Applicable for Sem - II):

Sr.No.	Course Code	Course
1.	CE 695	Cyber-Physical & Self-Organizing Systems
2.	CE 70G	Blockchain Technology
3.	CE 66A	Algorithmic Cryptanalysis
4.	CE699	Internet of Things
5.	CE 69B	Network Forensics
6.	CE 602A	Computational Intelligence
7.	CE 683	Information Warfare

8.	CE 70A	Formal Specification and Verification of Programs
9.	CE 700	Quantum Computing
10.	CE 70D	Computer Network Audit & Forensics
11.	CE 70E	Machine Learning with Python
12.	CE 70F	Cloud Computing
13.	CE 682	Secure Software Engineering
14.	CE 608	Simulation of Wargames
15.	MOOC	<i>Any relevant MOOC course for 3 credits upon (refer Page No-52)</i>
16.	CE71A	Reinforcement Learning
17.	CE601A	Interpretable and Explainable AI
	The electives and other Core Courses offered in the 2 nd semester by the other departments may be opted by the students on consultation with the course OIC/Department.	
	Maximum of 6 Credits can be opted by students as Professional Electives from the list of Online Courses on NPTEL/SWAYAM which are aligned to CSE Domain with During Semester II.	

CORE COURSES– SEMESTER-I

CORE COURSES – SEMESTER-I			
Course Code	Course Name	L – T – P	Credits
CS-601	Data Security & Privacy	3-0-0	03

Course Objectives: • The growth of importance of information security and privacy matters in the government and enterprise arenas has significantly broadened the scope of individuals who must be aware of relevant issues as part of their work. Security is becoming more of an element of existing roles such as records management, and new security roles such as Chief Information Security Officer are appearing in the enterprise. • Security considerations may become new elements of traditional responsibilities (e.g., programmers historically have been expected to document code, but now should be aware that failure to document may be a factor in a law enforcement investigation of whether a data breach was foreseeable). • This course will help students to examine policy, and enterprise issues and problems related to security and privacy. Electronic data will be the focus. Discussions will take general approaches and also focus on specific technologies.
Course Contents Unit I Security Architectures Information Systems; Database management Systems; Information Security CIA; Information Security Architecture; Database Securitylevels’ Menances to Databases; Asset Types & their values. Unit II Database Security Methods Environments: Parallel DBs, Distributed DBs, Database security Methodology; Database Security Definition. Unit III Profiles, Password Policies, Privileges, and Roles Defining and using Profiles: Creating Profiles in SQL Servers & end-users; Password Policies, Privileges, Tables and Database Objects Privileges, Column-Level Privileges; Creating, Assigning, and Revoking User Roles. Unit IV Database Application Security Models: Security Models: Access Matrix Model, Access Modes Models; Application Types: Client/Server Application; Web Application, Data Warehouse, Data Stream Applications. Unit V Virtual Private Databases: VPD, Implementation, VPD Row Col Security. Unit VI Database Auditing Models Technical Audit Environment, Process, Objectives, Classification Types, Incidence Reports, Level of escalations. Application Data Audit: DML Action Audit; Triggers; Fine-Grained Auditing FGA; Application Errors; PL-SQL Environments, Audit DB Activities. Unit VII Evolving Models & Security: Big Data; Data Streams; Structured, Unstructured, SQL and NOSQL, Block Chains, NFTs; Database Trojans, SQL Attachments in e-mails; Anatomy of vulnerability SELECT Encrypt data-at-rest & data-at-transit, Data and AIML Models. Project Cases data Security and Privacy: Online Databases; CSV files to Structured Environments, SCADA, IoTs.
Course Outcomes

After completing this course, the students will be able to: CO1: Student will be able to examine and identify Data Models for various applications + A general background in concepts of privacy at National & International Scenarios CO2: Student will be able to apply data abstraction & normalization techniques to handle volume and veracity + An understanding of how automation is changing the concepts and expectations concerning privacy and the increasingly interconnected issue of security; CO3: Student will be able to analyze & apply multi- dimensional data models for complex scenarios + Knowledge of technologies and regulations concerning information security from both data protection and law enforcement perspectives. CO4: Student will be able to propose solutions using various data models to cater special application requirements & to form a base to apply Data Mining & AIML techniques. + Use Case Study and apply Knowledge of the role of private regulatory and self Help efforts.
Text Books
1. Hassan A. Afyouni,—Database Security and Auditing, Third Edition, Cengage Learning, 2009. 2. Ron Ben Natan, Implementing Database Security and Auditing, Elsevier Digital Press, 2005
Reference Books
1. Charu C. Aggarwal, Philip S Yu —Privacy Preserving Data Mining I: Models and Algorithms, Kluwer Academic Publishers, 2008

Course Code	Course Name	L – T – P	Credits
CS-602	Machine Learning for Cyber Security	3-0-0	03
Course Objectives: To provide the knowledge of programming language as it applies to data analytics. Skills will be developed for articulate and explain which problems in Cyber Security may be solvable with Machine Learning. Student will learn various ML techniques including Supervised, unsupervised classification and regression analysis, Artificial Neural Networks, etc. for solving Cyber Security problems such as malware analysis, intrusion detection, spam filtering, fraud detection, online behaviour analysis etc. Student will learn Python Programming for implementing these algorithms on standard datasets to develop tools for cyber defense using machine learning.			
Course Contents			
Unit I Data Analytics Foundations: R programming, Python Basics -Expressions and Variables, String Operations, Lists and Tuples, Sets, Dictionaries Conditions and Branching, Loops, Functions, Objects and Classes, Reading/Writing files, Handling data with Pandas, Scikit Library, Numpy Library, Matplotlib, scikit programming for data analysis, setting up lab environment, study of standard datasets. Introduction to Machine Learning- Applications of Machine Learning, Supervised, unsupervised classification and regression analysis.			
Unit II Python libraries suitable for Machine Learning Feature Extraction. Data pre-processing, feature analysis etc., Dimensionality Reduction & Feature Selection Methods, Linear Discriminant Analysis and Principal Component Analysis, tackle data class imbalance problem, Supervised and regression analysis, Regression, Linear Regression, Non-linear Regression, Model evaluation methods, Classification, K-Nearest Neighbor, Naïve Bayes, Decision Trees, Logistic Regression, Support Vector Machines, Artificial Neural Networks, Model Evaluation. Ensemble Learning, Convolutional Neural Networks, Spectral Embedding, Manifold detection and Anomaly Detection.			

Unit III Unsupervised classification K-Means Clustering, Hierarchical Clustering, Density-Based Clustering, Recommender Systems- Content-based recommender systems, Collaborative Filtering, machine learning techniques for standard dataset, ML applications.			
Unit IV Case studies on Cyber Security problems that can be solved using Machine learning like Malware Analysis, Intrusion Detection, Spam detection, Phishing detection, Financial Fraud detection, Denial of Service Detection., advanced topics like applications of gen AI/discriminative AI in offensive/defensive scenarios, case study on GAN and deepfakes.			
Course Outcomes			
After completing this course, the students will be able to: CO1: Students will be able to understand ML paradigms and various Supervised, unsupervised classification and regression analysis methods. CO2: Students will be able to understand various ML algorithms like and analyse their applications in real world. CO3: Students will be able to understand advanced ML algorithms and techniques etc. CO4: Students will be capable of applying their ML knowledge and skills to solve engineering problems in various domains using ML programming languages in Cyber security domain.			
Text Books			
1. Building Machine Learning Systems with Python – Willi Richert, Luis Pedro Coelho. 2. Alessandro Parisi, Hands-On Artificial Intelligence for Cybersecurity: Implement smart AI systems for preventing cyber-attacks and detecting threats and network anomalies Publication date: Aug 2, 2019, Packt, ISBN-13, 9781789804027 3. Machine Learning: An Algorithmic Perspective – Stephen Marsland 4. Sunita Vikrant Dhavale, “Advanced Image-based Spam Detection and Filtering Techniques”, IGI Global, 2017. 5. Dhavale, S. V. (2019). Constructing an Ethical Hacking Knowledge Base for Threat Awareness and Prevention (pp. 1-305). Hershey, PA: IGI Global. 6. Soma Halder , Sinan Ozdemir, Hands-On Machine Learning for Cybersecurity: Safeguard your system by making your machines intelligent using the Python ecosystem, By Publication date : Dec 31, 2018, Packt, ISBN-13 :9781788992282			
Reference Books			
1. Stuart Russell, Peter Norvig (2009), “Artificial Intelligence – A Modern Approach”, Pearson Elaine Rich & Kevin Knight (1999), “Artificial Intelligence”, TMH, 2nd Edition 2. NP Padhy (2010), “Artificial Intelligence & Intelligent System”, Oxford 3. ZM Zurada (1992), “Introduction to Artificial Neural Systems”, West Publishing Company Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/ NVidia sources.			

Course Code	Course Name	L – T – P	Credits

CS-603	Applied Cryptography	3-0-0	03
Course Objectives: Understanding of basic encryption and authentication schemes and issue related to cryptanalysis and be able to determine the strength and weakness of the encryption/authentication schemes.			
Course Contents Unit I Classical Encryption Techniques and their Cryptanalysis: Symmetric cipher model, Substitution techniques, Transposition techniques, Steganography, One-Time Pad (Vernam's Cipher), Limitations of Perfect Secrecy, Shannon's Theorem. Unit II Private-Key Encryption Schemes and Block Ciphers: Pseudorandom Functions and Permutations, Private-Key Encryption Schemes from Pseudorandom Functions, DES – The Data Encryption Standard, Attacks on DES, Single-Round DES, Two-Round DES, Three-Round DES, Brute Force Search, Best Known Attacks on Full DES, AES, Stream cipher A5. Unit III Number Theory: Prime numbers and factoring, modular arithmetic, computations in finite fields, Cyclic Groups, Euclidian Algorithms, Miller-Rabin Primality Test, Chinese Remainder Theorem Discrete logarithms. Unit IV Public-Key (Asymmetric) Cryptography: Public-Key Problems and Mathematical Background, Diffie- Hellman Key Agreement, El-Gamal Encryption Scheme, RSA Encryption, Security of RSA, Hybrid Encryption , Attacks on RSA, Private and Public-Key Reversal, Common Modulus Attack, Simplified Broadcast Attack, Timing Attacks, Elliptic Curve Cryptography. Unit V Hash Functions: Definition and Properties, Constructions of Collision-Resistant Hash Functions, Random Oracle Model. Birthday Problems, Hashalgorithms:MD5,SHA-256.Message Authentication, Digital Signatures and Applications, Definitions, Constructions, Certificates and Public- Key Infrastructure, Combining Encryption and Signatures – Sign Cryption. Unit VI Homomorphic Encryption, Differential Privacy, Multiparty Computation, Functional Encryption.			
Course Outcomes			
After completing this course, the students will be able to: CO1: Students will be able to understand and analyze Private keys encryption schemes. CO2: Students will be able to understand public keys encryption schemes and able to perform the cryptanalysis CO3: Students are able to understand and design new schemes for information security. CO4: Students will be able to understand and design new schemes for end user's authentication & secure Communication			
Text Books			
1. "Cryptography & Network Security" by William Stallings 4th Edition, Pearson Education Asia. 2. Kahate A, "Cryptography & Network Security", Tata McGraw Hill. 3. Post-Quantum Cryptography by Daniel J. Bernstein, Johannes, Buchmann, Erik Dahmen, Springer. ISBN: 978-3-540-88701-0. 4. "Applied Cryptology" by Schiner Bruce, John Wiley & Sons			

Reference Books	
1. “Applied Cryptology” by Schiner Bruce, John Wiley & Sons. 2. “Introduction to Cryptography with Coding Theory” by Wade Trappe & Lawrence C Washington, New Jersey, Pearson Education. 3. Charlie Kaufman, Radia Perlman and Mike Speciner, “Network Security: Private Communication in a Public World”, Prentice Hall of India Private Limited. 4. Behrouz A. Forouzan, “Cryptography and Network Security”, McGraw Hill 5. Jonathan Katz and Lindell, “Introduction to Modern Cryptography: Principles and Protocols”, Chapman and Hall/CRC.	

Course Code	Course Name	L – T – P	Credits
CS-604	Advanced System Security	3-0-0	03
Course Objectives: • To learn designing and building a secure operating system, ensuring the enforcement of system security goals and evaluating the OS w.r.t necessary and sufficient conditions. • This includes learning and understanding- • The security architectures of current operating systems • Distinct approaches to building secure operating systems and Challenges in implementation • Concept of virtualization • Explore a range of existing problems and tensions in modern systems’ security			
Course Contents			
Unit I Security Principles: CIA triad; Operating System Security goals, Trust model, Threat model; Protection system; Reference monitor concept. Distributed System Security Goals. Access Control: Discretionary protection system, Mandatory protection system, Authentication and Role Based Access Control, Authorization and Attribute Based Access Control, Rule-based access control.			
Unit II Multics: Multics security fundamentals, protection system models, vulnerability analysis. Security in Commercial Operating Systems: protection system, authorization, security analysis for Unix-like and Windows OS. Security in Distributed Systems.			
Unit III Security Models for Information flow, secrecy models, integrity models. Capability system fundamentals & Case study Virtualization, Hypervisors and Sandboxing.			
Unit IV Threat Vectors, Threat Intelligence, Memory exploits, code based attacks; buffer overflow attacks; Hardware Security: H/w trojans, Hardware based root of trust, Side Channel Attacks & Micro-architectural attacks. Case Studies of OS exploits & Security enhanced OS: student presentation & interactive sessions.			

Course Outcomes	
After completing this course, the students will be able to: CO1: Understand the System Security concept. Learn the security terminology and models. Identify the components in building a secure OS. CO2: Analyse and Assess the security mechanisms in in earlier implemented secure OS and the contemporary commercial OS. Assess the vulnerabilities and challenges. CO3: Learn the Security policy models. Apply the policy and mechanism to building secure operating systems based on the security goals. Analyse and evaluate the distinct approaches for Secure OS design using VM. CO4: Practically realize the exploits of security mechanism and prevention mechanism to appreciate a Systems' security level.	
Text Books	
1. Jaeger, T., "Operating System Security", Morgan & Claypool (online), 2008. 2. Wenliang Du, "Computer & Internet Security: A Hands-on Approach", 1 May 2022 3. Mukhopadhyay, Debdeep, and Rajat Subhra Chakraborty. Hardware security: design, threats, and safeguards. CRC Press, 2014.	
Reference Books	
1. Matt Bishop, "Computer Security", Addison Wesley, 2002 2. Morrie Gasser: "Building a Secure Computer System" 3. Silberschatz and Galvin: "Operating System Concepts", Addison Wesley, 2006 4. Virgil Gligor's Lectures on Security Policies. 5. Bootstrapping Trust in Modern Computers, Byron Parno, Jonathan M, Adrian Perrig, Springer.	

Course Code	Course Name	L – T – P	Credits
CS-606L	Cyber Security Skill Development Lab Course– Semester 1	3-0-0	03
Course Objectives: • Analyse and evaluate advanced cyber threats in the context of security. • Design and implement secure systems and robust cyber defense mechanisms. • Conduct forensic investigations and ethical hacking exercises ethically. • Apply innovation and entrepreneurship principles to develop cyber security solutions. • Demonstrate leadership, teamwork, and communication in solving cyber security problems.			
Course Contents Unit I Secure Systems Architecture & Defensive Mechanisms - TLS, IPSec, DNSSEC - Secure Design Principles - Zero Trust Architecture - Layered Security, Firewalls - AI-Enhanced Defence Unit II Cyber Threat Landscape & National Security Context - APTs, Espionage, Terrorism - Stuxnet, SolarWinds, etc.			

- National/Global Cyber Policies - Role of DRDO, CERT-In, Tri-services - Attack Surfaces, Nation-State Actors Unit III Cyber Forensics, Ethical Hacking & Compliance - FTK, Autopsy, SleuthKit - Evidence Handling, Chain of Custody - Malware Analysis, Reverse Engineering - Pen Testing, Vulnerability Scanning - GDPR, ISO 27001, IT Act Unit IV Innovation, Startups & Cybersecurity Entrepreneurship - Startup Case Studies - Gov. Schemes (MeitY, iDEX, DRDO) - Product Lifecycle - Project Ideation, Proposal Drafting
Course Outcomes
After completing this course, the students will be able to: CO1: Analyse and evaluate cyber threats and vulnerabilities in security and enterprise contexts. CO2: Design secure systems, networks, and protocols using best practices and emerging technologies. CO3: Conduct ethical hacking, penetration testing, and forensic analysis using industry-standard tools. CO4: Innovate and propose cyber security solutions with a focus on entrepreneurship and real-world impact.
Text Books
1. Balagurusamy, E. (2019). Object-Oriented Programming with C++ (7th ed.). McGraw Hill Education. 2. Taneja, S. (2021). Python Programming: A Modular Approach. Pearson India. (Covers beginner to intermediate Python with examples tailored) 3. Kogent Learning Solutions Inc. (2008). SQL: The Complete Reference. Dreamtech Press. (Indian-oriented SQL book with comprehensive coverage and practical exercises). 4. Stroustrup, B. (2013). The C++ Programming Language (4th ed.). Addison-Wesley. 5. Lutz, M. (2013). Learning Python (5th ed.). O'Reilly Media. 6. Downey, A. B. (2015). Think Python: How to Think Like a Computer Scientist (2nd ed.). O'Reilly Media. [Free/Open Access] 7. Forta, B. (2012). SQL in 10 Minutes, Sams Teach Yourself (4th ed.). Sams Publishing. 8. Cook, S. (2012). CUDA Programming: A Developer's Guide to Parallel Computing with GPUs. Morgan Kaufmann. 9. Acharya, T., & Panigrahi, S. (2011). Foundations of Computer Networking. Wiley India. (Strong focus on practical network setups with lab infrastructure considerations.) 10. Kurose, J. F., & Ross, K. W. (2021). Computer Networking: A Top-Down Approach (8th ed.). Pearson. 11. Forouzan, B. A. (2007). Data Communications and Networking (4th ed.). McGraw-Hill Education. 12. Wireshark Foundation. (n.d.). Wireshark User Guide. [Online Resource] 13. Cisco Networking Academy. (n.d.). Cisco Packet Tracer Tutorials and Labs. [Online Resource] https://www.netacad.com

14. Joshi, R. C., & Belokar, G. R. (2020). Cybersecurity: Understanding Cyber Crimes, Computer Forensics and Legal Perspectives. Wiley India.
15. Stallings, W. (2020). Network Security Essentials: Applications and Standards (6th ed.). Pearson.
16. Weidman, G. (2014). Penetration Testing: A Hands-On Introduction to Hacking. No Starch Press.
17. Ness, J. (2008). Hacking: The Art of Exploitation (2nd ed.). No Starch Press.
18. National Institute of Standards and Technology. (2008). NIST SP 800-115: Technical Guide to Information Security Testing and Assessment. U.S. Department of Commerce.
19. Umesh, H. S., & Manjunath, S. G. (2022). Cyber Security and Ethical Hacking. Wiley India. (Includes labs for red/blue teaming and system auditing with edge and mobile devices.)
20. Mishra, A., & Sharma, A. K. (2019). Internet of Things (IoT) and Cyber Security. BPB Publications. (Focused on IoT device security, real-world case studies)
21. Sanders, C. (2017). Practical Packet Analysis: Using Wireshark to Solve Real-World Network Problems (3rd ed.). No Starch Press.
22. MITRE Corporation. (n.d.). MITRE ATT&CK® Framework Documentation. [Online Resource]
23. OWASP Foundation. (n.d.). OWASP Top 10: Web Application Security Risks. [Online Resource]
24. NIST. (2015). SP 800-160: Systems Security Engineering. U.S. Department of Commerce

Reference Books

1. Anderson, R. J. (2020). Security Engineering: A Guide to Building Dependable Distributed Systems (3rd ed.). Wiley. [Also freely available online]
2. IEEE, ACM Digital Library. (n.d.). Recent journals and conference proceedings in cybersecurity, AI & system engineering.
3. Springer, ResearchGate. (n.d.). Access to latest research for postgraduate dissertations and lab project references.

CORE COURSES – SEMESTER IIS

	CORE COURSES – SEMESTER II		
Course Code	Course Name	L – T – P	Credits
CS-611	Digital Forensics	3-0-0	03
Course Objectives:			
Course Contents			
Unit I Introduction to digital forensics -Stages of Forensic: acquisition or imaging of exhibits, analysis and reporting standards Introduction to Computer Forensics: Digital Devices with rudimentary computing power Acquisition or imaging of Onboard Memory and Static Memory Introduction to legal issues, Analysis and Reporting Standards, Online and Live Forensics.			
Unit II Forensic study of database and their metadata, database contents, log-files for creating timeline or recover relevant information.			
Unit III MFT & Registry Hives Extraction from Windows OS through Tools and Scripts Data Carving Using Open-Source Tools, Data Recovery and Secure deletion on Storage media. Evidence or Intrusion detection from internet logs, monitoring and analysis of network traffic. Internet of Things.			
Unit IV Drone Forensics: Internal and External Memory Artifacts Analysis of DJI Drone Models, Study of Various Drone- Components and their Artifacts, Fly-Path Reconstruction, Directory Analysis, Telemetry Data Recovery from Internal and External Memory of particular Drone Model			
Course Outcomes			
After completing this course, the students will be able to: CO1: Students will be able to understand the standard procedures of Digital Forensics required for Cyber Crime Investigation. CO2: Students will be able to apply proper commands and procedures required for digital investigation. CO3: Students can practically demonstrate or articulate the suspicious activity/artifacts extraction w.r.t. from the digital evidence. CO4: Students will be able to solve the real-time case-studies available on benchmarked repositories			
Text Books			
1. Kanellis, Panagiotis, “Digital Crime and Forensic Science in Cyberspace”, IGI Publishing”, ISBN 1591408733. 2. Marshall, Angus M. (2008), “Digital Forensics: Digital Evidence in Criminal Investigation”, Wiley-Blackwell, ISBN 0470517751 3. Brain Carrier, “File System Forensics Analysis”, Addison-Wesley Professional, 1st Edition, 2005			
Reference Books			
1. Chris Prosise, Kevin Mandia “ Incident Response & Computer Forensics", McGraw-Hill, 2nd Edition, 2003 2. Rick Ayers, Sam Brothers, Wayne Jansen, “Guidelines on Mobile Device Forensics”, NIST, US Dept. of Commerce, Revision 1, 2014			

Course Code	Course Name	L – T – P	Credits
CS-612	Reverse Engineering & Malware Analysis	3-0-0	03
Course Objectives: • The course introduces techniques for reverse engineering of binary applications and further focuses on applying these techniques for detecting, analyzing, and eradicating malware. It involves. • Learning the low-level details of executable binary on multiple operating systems. • Understand the Assembly code and use tools to analyze any binary file manually. • Tools and techniques to automate the process. • Techniques to prevent reversing of any binary. • Common vulnerabilities and protections in binary. • Static and dynamic malware analysis.			
Course Contents Unit I Introduction to reverse engineering; Low level perspective of software; Linux & Windows OS fundamentals; Compilers, Execution Environments; Executable file formats for multiple OS's; Reversing tools, Disassemblers, Debuggers, Decompilers, System monitoring tools; Unit II Assembly language primer; Calling Conventions; Offline code analysis; Debugging binary code; Runtime reverse engineering methods; Unit III Anti-reversing techniques, Breaking protections Reversing '.NET', De-compilation; Software vulnerabilities – buffer overflow, integer overflow, vulnerabilities exploitation, mitigation; Return oriented programming; Unit IV Introduction to malware; Reversing malware – Static & Dynamic malware analysis techniques; Evasive techniques; Packers & compression, Sandboxing executables & runtime analysis; Fileless Malware; Malware classification; Case Studies, linux binary analysis ,Student Presentation & Interactive Sessions			
Course Outcomes			
After completing this course, the students will be able to: CO1: Reverse engineer a binary executable file in an understandable form. CO2: Interpret the high level meaning of given assembly code. Detect the vulnerabilities in the executable code. CO3: Identify the different types of binary analysis methods to recognize the binary with evasive, anti- reversing mechanism. CO4: Perform code analysis and recognize common malware characteristics. Setup an environment for malware analysis and perform runtime analysis. Understand and trace process execution on a system.			
Text Books			

1. Eldad Eilam, “Reversing: Secrets of Reverse Engineering”, Wiley publishing, 2005. 2. Malware Analysis and Detection Engineering: A Comprehensive Approach to Detect and Analyze Modern Malware, by Abhijit Mohanta (Author), Anoop Saldanha, September 2020.
Reference Books
1. Michael Ligh, Steven Adair, “Malware Analysts’s cookbook & DVD”, Wiley publishing. 2. Michael Sikorski and Andrew Honig, Practical Malware Analysis, No Starch Press, 2012. 3. Abhishek Singh, “Identifying Malicious Code through Reverse Engineering”, Springer Publications, 2009. ISBN No – 978-0-387-09824-1. 4. Erik Buchanan, Ryan Roemer, Hovav Shacham, and Stefan Savage. 2008. “When good instructions go bad: generalizing return-oriented programming to RISC.”

Course Code	Course Name	L – T – P	Credits
CS-607L	Cyber Security Advanced Skill Development Lab – Semester 2	3-0-0	03
Course Objectives: • Analyse and evaluate advanced cyber threats in the context of security. • Design and implement secure systems and robust cyber defense mechanisms. • Conduct forensic investigations and ethical hacking exercises ethically. • Apply innovation and entrepreneurship principles to develop cyber security solutions. • Demonstrate leadership, teamwork, and communication in solving cyber security problems.			
Course Contents Unit I Advanced Penetration Testing (Red Team Simulation), Active Directory Exploitation and Defence, Secure Software Development Lifecycle (SSDLC), Advanced Malware Reverse Engineering, Threat Hunting and MITRE ATT&CK Mappin, Cloud Security Hardening and Monitoring, Threat Intelligence & Hunting (incl. OSINT, STIX/TAXII), Incident Response, Fundamentals of SOC/SOAR (Security Orchestration, Automation, and Response) Mid-Term Test 1 Coverage: Assignments 1–6 Format: MCQs, scenario-based questions, one lab-based problem to implement/demonstrate. Unit II Secure Containerization and Kubernetes Defense, Digital Forensics in Enterprise Breach Investigation, Building and Bypassing Security Controls, Zero Trust Architecture Simulation, Red vs Blue Team Capture the Flag, Advanced Risk Assessment and Compliance AuditMid-Term Test 2 Coverage: Assignments 7–12 Format: Real-world case analysis, technical description, hands-on challenge/CTF. Unit III Cyber-Range assignments, Mini-Project. Final Evaluation: [Marks50] Coverage: All above. Format: Real-world case analysis, technical description, hands-on. Evaluation Committee with one external expert.			
Course Outcomes			

After completing this course, the students will be able to:

CO1: Analyse and evaluate cyber threats and vulnerabilities in security and enterprise contexts.

CO2: Design secure systems, networks, and protocols using best practices and emerging technologies.

CO3: Conduct ethical hacking, penetration testing, and forensic analysis using industry-standard tools.

CO4: Innovate and propose cyber security solutions with a focus on entrepreneurship and real-world impact.

Text Books

1. Hacking: The Art of Exploitation – Jon Erickson
2. The Web Application Hacker's Handbook – Dafydd Stuttard, Marcus Pinto, Wiley.
3. Red Team Field Manual (RTFM) – Ben Clark
4. Practical Malware Analysis – Michael Sikorski, Andrew Honig
5. Applied Network Security Monitoring – Chris Sanders, Jason Smith, O'Reilly
6. The Hacker Playbook 3: Practical Guide To Penetration Testing – Peter Kim
7. Cybersecurity and Cyberwar: What Everyone Needs to Know – P.W. Singer, Allan Friedman, Oxford University Press
8. Cloud Security and Privacy – Tim Mather, Subra Kumaraswamy, Shahed Latif, O'Reilly
9. Kubernetes Security and Observability – Brendan Creane, Amit Gupta, O'Reilly
10. NIST Special Publication 800-53 Rev 5 – Security and Privacy Controls for Federal Information Systems, NIST.gov

Reference Books

1. Hacking: The Art of Exploitation – Jon Erickson
2. The Web Application Hacker's Handbook – Dafydd Stuttard, Marcus Pinto, Wiley.
3. Red Team Field Manual (RTFM) – Ben Clark
4. Practical Malware Analysis – Michael Sikorski, Andrew Honig
5. Applied Network Security Monitoring – Chris Sanders, Jason Smith, O'Reilly
6. The Hacker Playbook 3: Practical Guide To Penetration Testing – Peter Kim
7. Cybersecurity and Cyberwar: What Everyone Needs to Know – P.W. Singer, Allan Friedman, Oxford University Press
8. Cloud Security and Privacy – Tim Mather, Subra Kumaraswamy, Shahed Latif, O'Reilly
9. Kubernetes Security and Observability – Brendan Creane, Amit Gupta, O'Reilly
10. NIST Special Publication 800-53 Rev 5 – Security and Privacy Controls for Federal Information Systems, NIST.gov

Elective Courses – SEMESTER I/II

Course Code	Course Name	L – T – P	Credits
CS-605	Network and Cloud Security	3-0-0	03
Course Objectives: • Understanding basic issues, concepts, principles and mechanisms in Network and Cloud Security. • Basic Security concepts • Authentication • Access Control • IPSec and Internet Key Management • SSL/TLS Protocol • Firewall/UTM • Malicious Software • Intruder Detection Systems • Cloud Computing and Security. • Be able to determine appropriate mechanisms for protecting networked systems. • Network and Cloud Security Laboratory, Gain practical experience in configuring and testing security mechanisms through laboratory exercises. • Acquire in-depth knowledge of Network and Cloud Security Protocols, Appliances, and Systems. • Develop hands-on skills in identifying, executing (in controlled environments), and mitigating various network and cloud-based attacks.			
Course Contents Unit I Introduction, OSI security Architecture, Security Principles, Attacks and Threats, Model of Network Security; Security at Application Layer: Email Architecture, PGP, S/MIME Security at Transport Layer: SSL Architecture, TLS, SET, HTTPS protocols; Security at Network Layer, IPSec, VPN, ISKMP. Unit II Firewall: Types of Firewalls, Firewall configuration, DMZ, UTMs Intrusion Detection and Intrusion Prevention Systems, Honeypots, Distributed IDS, Password Management Authentication: kerberos, X509, Authentication, PKI, Security Information and Event Management (SIEM). Unit III Wireless Security: Wireless LAN, 802.11 Standards, Security of WLAN Cloud Security: Cloud Computing, Security Issues and Challenges, Applications, Cloud Service Models (IaaS, PaaS, SaaS) and their security implications. Data Security in Cloud (encryption, key management, data residency). DDoS : Direct, Reflector and Amplifier Attacks, TCP Syn Flooding, Countermeasures, Digital Attack Maps, DDoS mitigation techniques and services. Unit IV Malicious Software: Viruses, Worms, Ransomware etc, Anti-virus Architecture, Generation of Anti-Virus, Types of Viruses; Network Reconnaissance, Traceroute, Port Scanning, ICMP Scanning, Sniffing, Probing Routers Miscellaneous topics and current developments, Dark Web Network Security Observatory: Monitoring Networks, Emerging Threats and Technologies, AI/ML in Cybersecurity.			
Course Outcomes			
After completing this course, the students will be able to: CO1: Students will be able to recall, understand, and apply fundamental Network and Cloud security Concepts along with various countermeasures. CO2: Students will be able to understand and apply Network and Cloud Security concepts, hardware, software, standards and policies required for an organization. CO3: Students will be able to analyze and articulate the importance of implementing Network and Cloud Security protocols, Devices, and policies.			

CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in Network and Cloud Security.
Text Books
1. William Stallings, “Network Security Essentials”, 6 th Edition, Pearson Education, 2019. 2. B. Menezes, “Network Security and Cryptography”, Cengage, 2013. 3. W. Du, “Computer and Internet Security: A Hands On Approach”, 3 rd Edition, 2022 3. Tim Mather (Author), Subra Kumaraswamy (Author), Shahed Latif (Author), Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance, O'Reilly Media; 1st edition (4 September 2009).
Reference Books
1. A Fadia, “Network Security: A Hacker’s Perspective”, Second Edition, Macmillan, 2013. 2. Bragg et al. “Network Security: The complete Reference”, McGraw Hill, 2004 3. Seedlabs: https://seedsecuritylabs.org/ (last accessed on 12th June 2022). 4. VK Pachghare, Cloud Computing, PHI, 2016.

Course Code	Course Name	L – T – P	Credits
CS-613	Security Standards & Penetration Testing	3-0-0	03
Course Objectives: • This course will provide an introduction to the different technical and administrative aspects of Information Security and Assurance. Along with the defensive mechanisms, it explores offensive security techniques encompassing ethical hacking and penetration testing. The objectives are: • Facilitate in gaining knowledge on information security management systems. • Facilitate gaining knowledge on security standards like ISO-27001 standards, TCSEC, ITSEC, Secure coding etc. • Train to be a competent information security professional by learning theoretical as well as practical ethical hacking and penetration testing knowledge.			
Course Contents			
Unit I Introduction to Information security, Security Functional Requirements, Security Design Principles, Cryptographic Tools, Common Criteria for Information Technology Security Evaluation, Information security management systems (ISMS), ISO27000 and other security standards, Management responsibility, Responsibilities of Chief Information Security Officer (CISO)			
Unit II Security audits and assurance, Information Security Policy, Standards, and Practices, Asset Management, Human Resource Security, Security awareness training, Physical Security, Risk Management, Business continuity planning, Disaster Recovery planning. Basics of SOC, SOAR and SIEM			
Unit III Penetration testing methodologies, steps, ethical hacking phases, setting up of virtual lab for experimentation - ethical hacking and penetration testing tools including tools set of Kali Linux,			

Metasploit, etc. ONSINT concepts, lifecycle and Case-study; Reconnaissance - Information gathering, Vulnerability research, Foot-printing, whois, DNS enumeration, Social Engineering, E - Mail Tracking, Web Spiders; Scanning & Enumeration- Sniffing techniques & tools, arp/icmp/tcp/ip host discovery, types of scanning, Ping sweep techniques, Nmap, command switches, SYN, Stealth, XMAS, NULL, IDLE, and FIN Scans; detecting OS fingerprinting, banner grabbing, Null Sessions, SNMP/DHCP/DNS enumeration, Proxy Servers, Anonymizers, HTTP Tunneling Techniques, IP Spoofing Techniques; Cryptographic Techniques, Threat hunting, security analysis and antivirus solutions Unit IV Attacking System and Maintaining Access– Password/hash cracking, etc.; Cover tracks and Erase Evidence, Disabling Auditing, Clearing the event Log; Case Studies: Malware attacks-Trojan, Backdoor, Viruses, Worms, DoS/DDoS; Windows Hacking; Linux Hacking; Web and Database Hacking; Google Hacking; Wireless Hacking; Mobile Hacking;
Course Outcomes After completing this course, the students will be able to: CO1: Learn, identify and apply the basic concepts, terminology, theories, models and methods in the field of information security management field. CO2: Design the policies for managing information security effectively adhering to ISO- 27001 standards, TCSEC, ITSEC, Secure coding practices etc. CO3: Design, implement, integrate and manage various security countermeasures/tools/mechanisms/best practices and penetration testing through hands- on activities CO4: Study, design and implement the attacks like Network Intrusion, DDOS, Malware attacks are carried out successfully by attackers.
Text Books 1. Michael E Whitman, Herbert J Mattord, “Principles of Information Security”, Course Technology, 3rd Edition, 2008. 2. William Stallings and Lawrie Brown, “Computer Security: Principles and Practice”, 2nd edition, Pearson, 2012. 3. Krutz, R. L. & Vines, R. D., “The CISSP and CAP Prep Guide”, Platinum Edition, New York, Wiley Publishing., 2006. 4. Nina Godbole, “Information Systems Security: Security Management, Metrics, Frameworks and Best Practices”, Wiley India Pvt Ltd, 2012. 5. Dhavale, S. V. (2019). Constructing an Ethical Hacking Knowledge Base for Threat Awareness and Prevention (pp. 1-305). Hershey, PA: IGI Global. 6. Stuart McClure, Joel Scambray, George Kurtz, “Hacking Exposed: n/w sec secrets and solutions”, Mcgraw Hill, 2012
Reference Books 1. Various Security Standards - ISO 27000 series published by ISO. 2. Department of Defense Standard, Department of Defense, “Trusted Computer System Evaluation Criteria”, Orange Book. 3. Dieter Gollmann, “Computer Security”, John Wiley and Sons, Inc., 3rd edition, 2011. 4. David Kennedy, Jim O’Gorman, Devon Kearns, and Mati Aharoni, “Metasploit pentest guide”, No starch Press, san Francisco, 2011. 5. Bastian ballman, “Understanding n/w hacks: attack and defense with python”, Springer, 2012. 6. Rich Annings, Himanshu Dwivedi, Zane Lackey, “Hacking Exposed Web 2.0”, Tata Mcgraw hill Edition.

7. Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Springer/IBM/EC-Council sources

Course Code	Course Name	L – T – P	Credits
CE695A	Cyber Physical Systems	3-0-0	03

Course Objectives:

Course Contents

Unit I

CPS: Introduction Main Concepts, Challenges; Background role of Computer Networks, Data, Algorithms

Unit II

Self-organising Systems, Self-organisation in Natural Systems Inspiring Self-organising Software,

Unit III

Agents and Multi-Agent Systems Computing trends, Data device proliferation, Confluence of trends

Unit IV

Technological and economic drivers Self- organisation Mechanisms, Stigmergy, Gossip, Trust and Reputation for Successful Software Self- organisation, Cooperation , Immune Systems, Holonic Multi-Agent Systems Engineering Artificial Self-organising Systems

Unit V

Engineering Self-organising Systems, Middleware Infrastructures for Self-organising Pervasive Computing Systems

Unit VI

CPS design Standards, Time Models, CPS Special Interest Groups and Mitre Commendations in Design and developments

Unit VII

Applications of Self-organising Software, Self- organisation in Constraint Problem Solving, Adaptive Trust Management, Security in Artificial Systems Project Cases: SCADA, Industry 4.0 applications, Telemedicine, Environment Monitoring, IoTs, etc.

Course Outcomes

After completing this course, the students will be able to:

CO1: Students will be able to understand the scope of applications of CPS.

CO2: Students will be able to analyse the various components of CPS

CO3: Students will apply mechanisms to enable autonomous and self-organising techniques.

CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in cyber and information security domain along with scope to apply AIML and build secure digitized systems.

Text Books

1. Self-Organising Software from Natural to artificial Adaptation, Di- MarzoSerugendo, ;Gleizer, M-p; Karageorgos, A (Eds), 2011, XVIII,462P; Hardcover ISBN:978-3642-17347-9 2. Cormen et al,Horowitz Sahani, BipinDesai, Korth et al. Kurose Ross
Reference Books
1. “Principles of Cyber-Physical Systems” - Rajeev Alur, MIT Press, 2015 2. Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006 3. Kurose and Ross, Top Down Approach of Computer Networks, Prentice Hall, 8th Edition 2021. 4. https://iveybusinessjournal.com/publication/why-big-data-is-the-new-competitive-advantage/https://www.cdsaonline.org/cps-standard/ 5. https://pages.nist.gov/cpspwg/ International Association for Automation Research Papers shared by the subject incharge

Course Code	Course Name	L – T – P	Credits
CE-70G	Blockchain Technology	3-0-0	03

Course Objectives:

Blockchain is an emerging technology platform for developing decentralized applications and data storage, The basic tenet of this platform is that it allows one to create a distributed and replicated ledger of events, transactions, and data generated through various IT processes with strong cryptographic guarantees of tamper resistance, immutability, and verifiability. The technology itself holds much more promise in various areas such as time stamping, logging of critical events in a system, recording of transactions, trustworthy e-governance etc. Many researchers are working on many such use cases such as decentralized public key infrastructure, self-sovereign identity management, registry maintenance, health record management, decentralized authentication, decentralized DNS, etc. Considering the need to disseminate the emerging concepts for students, we proposed a new course on blockchain technology, includes the fundamental design and architectural primitives of Blockchain, the system and the security aspects, along with various use cases from different application domains

Course Contents

Unit I

Basic Cryptographic primitives used in Blockchain – Secure, Collision-resistant hash functions, digital signature, public key cryptosystems, zero-knowledge proof systems

Unit II

Centralized Systems, Basic Distributed System concepts – distributed consensus and atomic broadcast, Double Spend Attack, Race Condition, Byzantine fault- tolerant consensus methods.

Unit III

Basic Blockchain – concepts to Bitcoin and contemporary, Puzzle friendliness, proof-of-work based consensus mechanisms, Merkle Trees, Proof of membership, operations of Bitcoin blockchain, crypto-currency as application of blockchain technology, Bitcoin Scripts. Applications of Bitcoin Scripts.

Unit IV

Ethereum Blockchain: Smart Contract, Introduction to Solidity Language, Proof of stake, Ethereum Network, Programme execution with EVM. Unit V Hyperledger fabric platform- Decomposing the consensus process, Hyperledger fabric components, Chaincode Design and Implementation of Hyperledger Fabric Unit VI IoTA : Formation of Tangle, Cumulative weight, Consensus in IoTA, Double Spending Attack. Beyond Cryptocurrency – applications of blockchain in cyber security, integrity of information, E- Governance and other contract enforcement mechanisms. Research Aspects in Blockchain.
Course Outcomes After completing this course, the students will be able to: CO1: Students will be able to Understand cryptographic and distributed system principles foundational to blockchain security. CO2: Students will be able to design and implement decentralized applications using blockchain platforms like Ethereum and Hyperledger. CO3: Students will be able to Evaluate novel consensus models and blockchain applications in emerging domains like IoT and e-Governance. CO4: Students will be able to explore current trends, challenges, and research directions in blockchain security.
Text Books 1. Bitcoin and Cryptocurrency Technologies by Arvind Narayanan, Joseph Bonneau, Edward Felten, Andrew Miller, Steven Goldfeder, Princeton University Press 2. “S. Shukla, M. Dhawan, S. Sharma, S. Venkatesan, ‘Blockchain Technology: Cryptocurrency and Applications’, Oxford University Press.
Reference Books 1. Josh Thompson, ‘Blockchain: The Blockchain for Beginnings, Guild to Blockchain Technology and Blockchain Programming’, Create Space Independent Publishing Platform

Course Code	Course Name	L – T – P	Credits
CE-66A	Algorithmic Cryptanalysis	3-0-0	03
Course Objectives: This course discusses cryptanalysis from basics to advanced application from algorithmic point of view. After completion of the course, the students should be able to identify and apply the suitable algorithm for more sophisticated cryptographic applications, including LFSR-based stream ciphers and index calculus methods. The students should be able to observe the advancements in current computer architectures and its impact on implementation aspects of cryptanalysis methods.			
Course Contents Unit I Preliminaries, Defining security in cryptography, Elementary Number Theory and Algebra, Evolution in Computing Devices, Evolution in Communication Media, Evolving Programming Environments, Three Generic Forms of Cryptanalysis: Cipher text only, Known cipher text/plain text pairs, and Chosen plain text or chosen cipher text. Unit II General Approaches to Cryptanalysis – (i) based on properties on encryption algorithms & (ii) brute force, Linear Algebra, Sieve Algorithms, Brute Force Cryptanalysis, The Birthday Paradox: Sorting or Not? Birthday-Based Algorithms for Functions, Algorithmic complexities & computational costs. Unit III Birthday Attacks through Quadrisection, Fourier and Hadamard–Walsh Transforms, Lattice Reduction, Polynomial Systems and Gröbner Bases Computations; Study of protocols for cryptanalysis. Unit IV Attacks on Stream Ciphers, Lattice-Based Cryptanalysis, Elliptic Curves and Pairings, Index Calculus Algorithms			
Course Outcomes After completing this course, the students will be able to: CO1: Students will be able to Understand cryptographic and distributed system principles foundational to blockchain security. CO2: Students will be able to design and implement decentralized applications using blockchain platforms like Ethereum and Hyperledger. CO3: Students will be able to Evaluate novel consensus models and blockchain applications in emerging domains like IoT and e-Governance. CO4: Students will be able to explore current trends, challenges, and research directions in blockchain security.			
Text Books 1. Joux, A. (2009). Algorithmic Cryptanalysis (1st ed.). Chapman and Hall/CRC. https://doi.org/10.1201/9781420070033 2. Mihailescu, Marius Iulian, and Stefania Loredana Nita. Pro Cryptography and Cryptanalysis: Creating Advanced Algorithms with C# and .NET. Apress, 2021.			

Reference Books	
1. Gaines, Helen F. Cryptanalysis: A study of ciphers and their solution. Courier Corporation, 2014. 2. Wagstaff Jr, Samuel S. Cryptanalysis of number theoretic ciphers. Chapman and Hall/CRC, 2019. 3. Derbez, Patrick. Tools and Algorithms for Cryptanalysis. Diss. Université Rennes 1, 2022. 4. Petrenko, Alexei. Applied Quantum Cryptanalysis. CRC Press, 2023.	

Course Code	Course Name	L – T – P	Credits
CE-606A	Software Engineering & System Modelling	3-0-0	03
Course Objectives: Major objective is to learn basic principles of Software Engineering and Design, which can facilitate the resource efficient model of the Software Systems.			
Course Contents Unit I Software Development Process, Planning software project, Cost, Scheduling and Risk Management. Metrics, Design Principles, Introduction to Object Oriented Design. Unit II Introduction to OOAD What is OOAD? What is UML? What are the Unified process (UP) phases, Case study the NextGen POS system, Inception-Use case Modelling, Relating Use cases include, extend and generalization Elaboration -Domain Models, finding conceptual classes and description classes, Associations, Attributes, Domain model refinement Finding conceptual class hierarchies, relationships, UML activity diagrams and modelling Unit III System sequence diagrams (SSD) -Relationship between sequence diagrams and use cases Logical architecture and UML package diagram, Logical architecture refinement, UML class diagrams, UML interaction diagrams Unit IV GRASP: Designing objects with responsibilities Creator, Information expert, Low Coupling, Controller, High Cohesion, Designing for visibility, Applying GoF design patterns adapter, singleton, factory and observer patterns. Unit V UML state diagrams and modelling -Operation contracts, Mapping design to code, UML deployment and component diagrams.			
Course Outcomes After completing this course, the students will be able to: CO1: Students will be able to understand Basic Principles of Software Engineering and Design . CO2: Students will be able to create Use Cases and develop Use Case Models of the Systems. CO3: Students will be able to apply UML design notations to develop the software systems.			

CO4: Students will be to recognize and apply appropriate software design patterns for software efficiency.
Text Books
1. Software Engineering- Pankaj Jalote, TMH Software Engineering- Ian Sommerville , Pearson Craig Larman, 2. "Applying UML and Patterns: An Introduction to object-oriented Analysis and Design and iterative development", Third Edition, Pearson Education
Reference Books
1. Mike O'Docherty, " Object-Oriented Analysis & Design: Understanding System Development with UML 2.0", John Wiley & Sons . 2. James W-Cooper, Addison- Wesley, "Java Design Patterns-A Tutorial", Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides, 3. "Design patterns: Elements of Reusable object-oriented software", - Addison-Wesley.

Course Code	Course Name	L – T – P	Credits
CE-695	Cyber-Physical & Self-Organizing Systems	3-0-0	03
Course Objectives: This course examines a new class of computational systems called Cyber-Physical Systems CPS. Such systems have the potential to provide far-reaching benefits in addressing some of the toughest problems we face as a society, such as: reducing healthcare costs, minimizing traffic congestion, and constructing zero-net energy buildings. Four important features characterize CPS: their ability monitors the underlying physical environment, reason about the monitored data, control the physical environment through actuation, in a coordinated manner using a communication medium. It can be seen immediately that in CPS, the computational element (cyber) and the environment (physical) are tightly coupled, with one influencing the other. CPS sits at the confluence of several traditional disciplines, such as: embedded systems, real-time systems, sensor networks, control and hybrid systems, and security. It presents many challenging problems and opportunities for research. With guidance from the professor, students will survey recent CPS publications, develop an aptitude. Readings will include papers on CPS applications (e.g., Body Area Networks, smart automobiles, and energy-efficient buildings), issues involved in designing CPS (e.g., monitoring, communication, and control), and how to ensure that the designed systems satisfy certain essential properties (e.g., safety and security).			
Course Contents Unit I CPS: Introduction Main Concepts, Challenges; Background role of Computer Networks, Data, Algorithms Unit II Self-organising Systems, Self-organisation in Natural Systems Inspiring Self-organising Software, Unit III Agents and Multi-Agent Systems Computing trends, Data device proliferation, Confluence of trends Unit IV Technological and economic drivers Self-organisation Mechanisms, Stigmergy , Gossip , Trust and Reputation for Successful Software Self-organisation Cooperation , Immune Systems, Holonic Multi-Agent Systems Engineering Artificial Self-organising Systems, Unit V Engineering Self-organising Systems, Middleware Infrastructures for Self-organising Pervasive Computing Systems 164 Unit VI Applications of Self-organising Software, Self-organisation in Constraint Problem Solving, Adaptive Trust Management, Security in Artificial Systems			
Course Outcomes			
After completing this course, the students will be able to: CO1: Students will be able to understand Basic Principles of Software Engineering and Design . CO2: Students will be able to create Use Cases and develop Use Case Models of the Systems. CO3: Students will be able to apply UML design notations to develop the software systems. CO4: Students will be to recognize and apply appropriate software design patterns for software efficiency.			

Text Books
1. Self-Organising Software from Natural to artificial Adaptation, Di- MarzoSerugendo, ;Gleizer, M-p; Karageorgos, A (Eds), 2011, XVIII,462P; Hardcover ISBN:978-3642-17347-9 2. Principles of Cyber-Physical Systems – Rajeev Alur, MIT Press, 2015 3. Research Papers discussed in the classroom discussions
Reference Books
1. Self-Organising Software from Natural to artificial Adaptation, Di- MarzoSerugendo, ;Gleizer, M-p; Karageorgos, A (Eds), 2011, XVIII,462P; Hardcover ISBN:978-3642-17347-9 2. Principles of Cyber-Physical Systems – Rajeev Alur, MIT Press, 2015 3. Research Papers discussed in the classroom discussions

Course Code	Course Name	L – T – P	Credits
CE-695	Network Forensics	3-0-0	03
Course Objectives: Network-Administrator & Network-Designer perspectives, develop skill sets to be resourceful in investigating the crimes in the area of Cyber-Security. Enhance analytical capabilities to evaluate a network.			
Course Contents			
Unit I Forensics: An Overview, Scope of Network Forensic, Network Forensics Basics 170			
Unit II Network Enabled Operations, Network Controlled Operations, Network Offences, Network Criminalistics Unit			
Unit III Basics of host devices on networks: Inter-Network Devices, OS and Networking: A Review			
Unit IV Advanced Topics in Computer Network Forensics, Network Forensic Modelling and Principles, Network Forensic Duplication, Network Forensics Analytics, Network File Carving, Network & Cyber Forensics Tools and the Testing of host devices in a network, Mobile Network Device Forensics, IPV6, Network Surveillance and Accountability, Network Attack Traceback and Attribution, Multicast Fingerprinting, Multimedia Forensics			
Unit V Intrusion and Online Frauds Detection			
Unit VI Peer-2-Peer Networks, Cryptocurrency and Blockchain			
Unit VII Network Traffic & Traffic engineering, Network Traffic & Traffic engineering for the Steganography & Steganalysis			
Unit VIII Anonymity/Pseudonymity/P2P environments, Network Forensic Challenges in adhoc environments, Network Forensic challenges in IoTs			
Unit IX			

Legal Perspective: Cyber Law, Security and Privacy Policies and Guidelines Unit X Case Studies, and ethical issues Unit XI: Court Testimony and Report Writing Skills
Course Outcomes
After completing this course, the students will be able to: CO1: Students will be able to understand Basic Principles of Software Engineering and Design . CO2: Students will be able to create Use Cases and develop Use Case Models of the Systems. CO3: Students will be able to apply UML design notations to develop the software systems. CO4: Students will be to recognize and apply appropriate software design patterns for software efficiency.
Text Books
1. Bruce Middleton, Cyber Crime Investigator's Field Guide, Boca Raton, Florida:Auerbach Publications, 2001, ISBN 0-8493-1192-6. 2. Brian Carrier, File System Forensic Analysis, Addison-Wesley, 2005, ISBN 0-321-26817-2. 3. Chris Prosise and Kevin Mandia, Incident Response: Investigating Computer Crime, Berkeley, California: Osborne/McGraw-Hill, 2001, ISBN 0-07-213182-9. 4. Warren Kruse and Jay Heiser, Computer Forensics: Incident Response Essentials, AddisonWesley, 2002, ISBN 0-201-70719-5. 5. Stephen Northcutt, Mark Cooper, Matt Fearnow, and Karen Frederick, Intrusion Signatures and Analysis, Indianapolis, Indiana: New Riders, 2001, ISBN 0-7357-1063-5.
Reference Books
1. Bruce Middleton, Cyber Crime Investigator's Field Guide, Boca Raton, Florida:Auerbach Publications, 2001, ISBN 0-8493-1192-6. 2. Brian Carrier, File System Forensic Analysis, Addison-Wesley, 2005, ISBN 0-321-26817-2. 3. Chris Prosise and Kevin Mandia, Incident Response: Investigating Computer Crime, Berkeley, California: Osborne/McGraw-Hill, 2001, ISBN 0-07-213182-9. 4. Warren Kruse and Jay Heiser, Computer Forensics: Incident Response Essentials, AdditionWesley, 2002, ISBN 0-201-70719-5. 5. Stephen Northcutt, Mark Cooper, Matt Fearnow, and Karen Frederick, Intrusion Signatures and Analysis, Indianapolis, Indiana: New Riders, 2001, ISBN 0-7357-1063-5.

Course Code	Course Name	L – T – P	Credits
CE-602A	Computational Intelligence	3-0-0	03
Course Objectives: The course goal is to make students familiar with basic principles of various computational methods of computational intelligence (CI) like nature-inspired methods (neural nets, evolutionary algorithms), fuzzy systems, as well as various probabilistic methods under uncertainty (e.g. Bayesian models) and machine learning methods (e.g. reinforcement learning). After the course the students will be able to conceptually understand the important terms and algorithms of CI, such that they would be able to choose appropriate method(s) for a given task.			
Course Contents Unit I Introduction to Computational Intelligence: Computational Intelligence Paradigms, Artificial Neural Networks, Evolutionary Computation, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, Supervised, unsupervised classification and regression analysis. Unit II Dimensionality Reduction & Feature Selection Methods: Linear Discriminant Analysis and Principal Component Analysis; Data Pre-Processing, Regression, Universal Approximation Unit III Evolutionary Computation: An Overview of Combinatorial Optimization, An Introduction to Genetic Algorithms, Theoretical Foundations of Genetic Algorithms, Genetic Algorithms in Engineering and Optimization, Genetic Algorithms in Natural Evolution, Unit IV Swarm Intelligence: Particle Swarm Optimization, Ant Colony Optimization Unit V Nature Inspired Algorithms for optimization: Differential Evolution, Simulated Annealing, Multi-objective Optimization, Hybrid Optimization Algorithms			
Course Outcomes			
After completing this course, the students will be able to: CO1: Students will be able to understand Basic Principles of Software Engineering and Design . CO2: Students will be able to create Use Cases and develop Use Case Models of the Systems. CO3: Students will be able to apply UML design notations to develop the software systems. CO4: Students will be to recognize and apply appropriate software design patterns for software efficiency.			
Text Books 1. Eberhart& Shi, —Computational Intelligence: Concepts to Implementations, Morgan Kaufmann,2007 2. Xin-She Yang, —Nature Inspired Optimization Algorithms, Elsevier, 2014			
Reference Books 1. Andries Engelbrecht (2007), —Computational Intelligence: an Introduction, Wiley 2. Amit Konar (2005), —Computational Intelligence: Principles, Techniques, and Applications, Springer-Verlag Berlin Heidelberg 3. Stuart Russell, Peter Norvig (2009), —Artificial Intelligence – A Modern Approach, Pearson Elaine Rich & Kevin Knight (1999), —Artificial Intelligence, TMH, 2nd Edition 4. NP Padhy (2010), —Artificial Intelligence & Intelligent System, Oxford			

5. ZM Zurada (1992), —Introduction to Artificial Neural Systems, West Publishing Company
6. Timothy J Ross (2004), —Fuzzy Logic with Engineering Applications, John Wiley & Sons Ltd

Course Code	Course Name	L – T – P	Credits
CE-70A	Formal Specification and Verification of Programs	3-0-0	03

Course Objectives:

To study methods and techniques for stating and proving the correctness statements. Studying Mathematical Logic (Symbolic Logic), Mathematical models for programs. (Programming Language Semantics) and Justification of the verification techniques

Course Contents

Reasoning about sequential programs: Programs as (possibly infinite) state transition systems; Specifying program correctness using pre- and post-conditions; partial and total correctness semantics; Hoare logic and its rules for a simple imperative sequential language; weakest pre-condition and strongest post-condition semantics; central importance of invariants in program verification. Brief introduction to lattices and the theory of abstract interpretation; some numerical abstract domains: intervals, difference bound matrices, octagons, polyhedra; computing abstract post-conditions and abstract loop invariants; refining abstractions and counterexample-guided abstraction refinement; Predicate abstraction and boolean programs; converting assertion to a location reachability problem; location reachability using predicate abstraction for simple programs and for programs with (possibly recursive) function calls; Introduction to temporal logics: LTL and CTL; Kripke structures as models of reactive (hardware and software) systems; LTL and CTL model checking algorithms and some applications

Course Outcomes

After completing this course, the students will be able to:

- CO1:** Students will be able to understand Basic Principles of Software Engineering and Design .
- CO2:** Students will be able to create Use Cases and develop Use Case Models of the Systems.
- CO3:** Students will be able to apply UML design notations to develop the software systems.
- CO4:** Students will be to recognize and apply appropriate software design patterns for software efficiency.

Text Books

1. Logic in Computer Science: Modeling and Reasoning about Systems, M. Huth and M. Ryan, Cambridge University Press, 2004
2. Chapter 15, Methods and Logics for Proving Programs by P. Cousot, in Handbook of Theoretical Computer Science, Vol B (Formal Models and Semantics), edited by Jan Van Leeuwen, The MIT Press, 1994

Reference Books

1. Research papers and survey articles to be announced in class

Cours e Code	Course Name	L – T – P	Credits
CE-700	Quantum Computing	3-0-0	03
Course Objectives: Quantum Computing" is among those terms that are widely discussed but often poorly understood. The reasons of this state of affairs may be numerous, but possibly the most significant among them is that it is a relatively new scientific area, and it's clear interpretations are not yet widely spread. The main obstacle here is the word "quantum", which refers to quantum mechanics - one of the most counter-intuitive ways to describe our world. But fear not! This is not a course on quantum mechanics. We will gently touch it in the beginning and then leave it apart, concentrating on the mathematical model of quantum computer, generously developed for us by physicists. This doesn't mean that the whole course is mathematics either (however there will be enough of it). We will build a simple working quantum computer with our bare hands, and we will consider some algorithms, designed for bigger quantum computers which are not yet developed. The course material is designed for those computer scientists, engineers and programmers who believe, that there's something else than just HLL programming, that will move our computing power further into infinity.			
Course Contents Unit I Introduction, Information and Computations, Characteristics of Computational Systems, Computability and Algorithms, Computational Complexity, Quantum Computing parameters and units, The Multiverse Interpretation of Quantum Mechanics Unit II Mathematical Model of Quantum Computing, Qubit, Qubit Measurement, Systems with Multiple Qubits, Measuring the Multiple Qubits Systems, Quantum System Evolution & Computations Unit III Quantum Computer and Quantum Algorithms, Deutsch's Problem, Quantum Computer Prototype, Suitable Algorithms Unit IV Shor's Algorithm, Factoring and the RSA, Factoring and Period Finding, Quantum Fourier Transform Unit V Grover's Algorithm. A Quantum Computer Application Boundaries, Grover's Algorithm, Challenges Unit VI Quantum environments, Search Spaces, Search Optimisation, Storage Optimisation, Quantum Resources, Future, Challenges			
Course Outcomes			
After completing this course, the students will be able to: CO1: Students will be able to understand Basic Principles of Software Engineering and Design . CO2: Students will be able to create Use Cases and develop Use Case Models of the Systems. CO3: Students will be able to apply UML design notations to develop the software systems. CO4: Students will be to recognize and apply appropriate software design patterns for software efficiency.			

Text Books
1. Nielsen, Michael A.; Chuang, Isaac L. (June 2012). Quantum Computation and Quantum Information (10th anniversary ed.). Cambridge: Cambridge University Press. ISBN 9780511992773. OCLC 700706156.
Reference Books
1. References: Research Papers as discussed in the class room.

Course Code	Course Name	L – T – P	Credits
CE-70D	Computer Network Audit & Forensics	3-0-0	03
Course Objectives: To meet end-user, Network-Administrator & Network-Designer perspectives, develop skill sets to be resourceful in the area of Cyber-Security. Enhance analytical capabilities to evaluate a Network and Network Enabled Operations to analyze Network Centric Operations			
Course Contents Unit I Basics of host devices on networks: Inter-Network Devices, OS and Networking: A Review, n-tier, peer-to-peer Network architectures Unit II Network Protocols, Network Enabled Operations, Network Controlled Operations, Network Offences, Network Criminalities Unit III Packet Analysis, Packet Analysis Tools, Network Audit & tools, Network Traffic Engineering, Network Analysis and Analytics Unit IV Network Forensics: An Overview, Scope of Network Forensic, Network Forensics Basics Unit V Computer Network Forensic Modelling and Principles, Network Forensic Duplication, Network Forensics Analytics, Network File Carving, Network & Cyber Forensics Tools and the Testing of host devices in a network, Mobile Network Device Forensics, IPV6, Network Surveillance and Accountability Unit VI Futuristic Networks, Dependable Networks, AI-Enabled Network Environments, Network Virtualization, SDNs, Sensor Networks, IoT, Evolution in Computing Environments like Cloud, Edge, Fog, Ubiquitous, Pervasive			
Course Outcomes			
After completing this course, the students will be able to: CO1: Students will be able to understand Basic Principles of Software Engineering and Design . CO2: Students will be able to create Use Cases and develop Use Case Models of the Systems. CO3: Students will be able to apply UML design notations to develop the software systems.			

CO4: Students will be to recognize and apply appropriate software design patterns for software efficiency.	
Text Books 1. James Kurose & Keith Ross, Computer Networking: A Top-Down Approach (6th Edition), ISBN-13: 978-0132856201 ISBN-10: 0132856204 2. Packet Analysis Tools, Network Audit Tools and Courseware	
Reference Books 1. Bruce Middleton, Cyber Crime Investigator's Field Guide, Boca Raton, Florida:Auerbach Publications, 2001, ISBN 0-8493-1192-6. 2. Brian Carrier, File System Forensic Analysis, Addison-Wesley, 2005, ISBN 0-321-26817-2. 3. Chris Prosise and Kevin Mandia, Incident Response: Investigating Computer Crime, Berkeley, California: Osborne/McGraw-Hill, 2001, ISBN 0-07-213182-9. 4. Warren Kruse and Jay Heiser, Computer Forensics: Incident Response Essentials, Addition Wesley, 2002, ISBN 0-201-70719-5. 5. Stephen Northcutt, Mark Cooper, Matt Fearnow, and Karen Frederick, Intrusion Signatures and Analysis, Indianapolis, Indiana: New Riders, 2001, ISBN 0-7357-1063-5. 6. Rebecca Gurley Bace, Intrusion Detection, Indianapolis, Indiana: Macmillan Technical, 2000, ISBN 1578701856. 7. Edward Amoroso, Intrusion Detection: An Introduction to Internet Surveillance, Correlation, Trace Back, Traps, and Response, Intrusion.Net Books, 1999, ISBN 0-9666700-7-8. 8. Ross Anderson, Security Engineering: A Guide to Building Dependable Distributed Systems, John Wiley & Sons, 2001, ISBN: 0471389226. 9. Alberto Leon-Garcia and Indra Widjaja, Communication Networks: Fundamental Concepts and Key Architectures, First Edition, McGraw-Hill Companies, Inc., 2000, ISBN 0-07-022839-6.	

Course Code	Course Name	L – T – P	Credits
CE-70F	Cloud Computing	3-0-0	03
Course Objectives: This course will introduce various aspects of cloud computing, including fundamentals, management issues, security challenges and future research trends. This will help students and researchers to use and explore the cloud computing platforms.			
Course Contents Unit I Introduction to Cloud Computing, Cloud Computing Architecture Unit II Service Management in Cloud Computing, Data Management in Cloud Computing Unit III Resource Management in Cloud, Cloud Security Unit IV Open Source and Commercial Clouds, Cloud Simulator Week 8 : Research trend in Cloud Computing, Fog Computing			

Course Outcomes
After completing this course, the students will be able to: CO1: Students will be able to understand Basic Principles of Software Engineering and Design . CO2: Students will be able to create Use Cases and develop Use Case Models of the Systems. CO3: Students will be able to apply UML design notations to develop the software systems. CO4: Students will be to recognize and apply appropriate software design patterns for software efficiency.
Text Books
1. Cloud Computing from Beginning to End by Ray J Rafaels 2. Cloud Computing: Concepts, Technology & Architecture by Zaigham Mahmood, Ricardo Puttini, Thomas Erl.
Reference Books
1. OpenStack Cloud Computing Cookbook by Kevin Jackson

Course Code	Course Name	L – T – P	Credits
CE-682	Secure Software Engineering	3-0-0	03
Course Objectives: Students will acquire an understanding of the fundamental concepts for developing secure systems • Introduce security requirements, Security Policies, Architecture of Secure Software and Boot Integrity • Attacker models • Fundamentals of data protection and privacy			
Course Contents Fundamentals of Software Engineering: Requirements Engineering, Design Concepts, Software Testing Fundamentals. Confinement, Boot integrity, Architectural approaches to building secure Software, Dynamic Root of trust for Measurement, Run- time enforcement of Security Policies, Software only root of trust (SWORT), Usable and Secure Password, Security Protocols and Verification, Static Analysis of software, Combining static and dynamic analysis, Control Flow Integrity, Language based Approaches to building Secure Software.VAPT analysis, secure coding Techniques.			
Course Outcomes			
After completing this course, the students will be able to: CO1: Students will be able to understand Basic Principles of Software Engineering and Design . CO2: Students will be able to create Use Cases and develop Use Case Models of the Systems. CO3: Students will be able to apply UML design notations to develop the software systems. CO4: Students will be to recognize and apply appropriate software design patterns for software efficiency.			
Text Books 1. Software Engineering - Roger S Pressman - 5th edition. 2. An Integrated Approach to Software Engineering, PankajJalote Third Edition, NarosaPublishing House 3. The security Development Lifecycle, by Michael Howard and Steve Lipner			

4. Security in Computing, By Charles P. Pfleeger , Shari Lawrence Pfleeger, Publisher: PrenticeHall Print ISBN-10: 0-13-239077-9
Reference Books
1. Threat Modeling by Frank Swiderski, Window Snyder, Microsoft Press, ISBN-10:0735619913
2. Research Paper and Articles in Journals and Conference Proceedings.

Course Code	Course Name	L – T – P	Credits
CE-699	Internet of Things - Elective	3-0-0	03

Course Objectives:

- Students will acquire an understanding of the fundamental concepts for developing IoT devices and software configuration required for IoT implementations.

Course Contents

Unit I

Introduction to Internet of Things, Definition and Characteristics of IoT, Physical Design of IoT, IoT Protocols, IoT communication models, IoT Communication APIs

Unit II

IoT enabling Technologies, Wireless Sensor Networks, Cloud Computing, Big data analytics, Communication protocols, Embedded Systems, IoT Levels and Deployment Templates, Domain Specific IoTs: Home, City, Environment, Energy, Retail, Logistics, Agriculture, Industry, health and Lifestyle

Unit III

IoT and M2M, Software defined networks, network function virtualization, difference between SDN and NFV for IoT, Basics of IoT System Management with NETCOZF, YANG, NETCONF, YANG, SNMP NETOPEER

Unit IV

IoT physical end devices & end points, IoT Physical Servers & Cloud offerings, Software environments, NEO, Security

Course Outcomes

After completing this course, the students will be able to:

CO1: Students will be able to understand Basic Principles of Software Engineering and Design .

CO2: Students will be able to create Use Cases and develop Use Case Models of the Systems.

CO3: Students will be able to apply UML design notations to develop the software systems.

CO4: Students will be to recognize and apply appropriate software design patterns for software efficiency.

Text Books

1. "Internet of Things: A Hands-on Approach", by ArshdeepBahga and Vijay Madisetti (Universities Press), 2014
2. "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by PethuruRaj and Anupama C. Raman (CRC Press)

Reference Books

1. "Designing the internet of things", McEwen, Adrian, and Hakim Cassimally. John Wiley & Sons, 2013.
2. Research Papers discussed in the classroom discussions.

Course Code	Course Name	L – T – P	Credits
CE-70E	Machine Learning with Python	3-0-0	03
Course Objectives: This course examines the tools and techniques required for learning machine learning algorithms. This course will provide an introduction to the subject and its various applications. Student will learn to implement ML algorithms in python for solving various problems.			
Course Contents Unit I Basic programming in Python, Introduction: Basic definitions, types of learning, hypothesis space and inductive bias, evaluation, cross-validation. Unit II Linear regression, Decision trees, overfitting. 178 Unit III Instance based learning, Feature reduction, Collaborative Filtering based recommendation. UNIT IV Probability and Bayes learning. Unit IV Logistic Regression, Support Vector Machine, Kernel function and Kernel SVM. Unit V Neural network: Perceptron, multilayer network, backpropagation, introduction to deep neural networks. Unit VI Clustering: k-means, Gaussian mixture model.			
Course Outcomes			
After completing this course, the students will be able to: CO1: Students will be able to understand Basic Principles of Software Engineering and Design . CO2: Students will be able to create Use Cases and develop Use Case Models of the Systems. CO3: Students will be able to apply UML design notations to develop the software systems. CO4: Students will be to recognize and apply appropriate software design patterns for software efficiency.			
Text Books			
1. Geron Aurelien, —Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, O'Reilly, 2017. 2. Jerome H. Friedman, Robert Tibshirani, and Trevor Hastie, —The Elements of Statistical Learning, Springer, 2001.			
Reference Books			
1. Sebastian Raschka, —Python Machine Learning, Packt, 1st Edition, 2015			

LIST OF MOOC COURSE FOR 3 CREDITS

Sr No.	Course ID	Course Name	SME Name	Institute	Duration	PG
1	noc25-cs86	Distributed Optimization and Machine Learning	Prof. Mayank Baranwal	IIT Bombay	12 Weeks	PG
2	noc25-cs98	Applied Accelerated Artificial Intelligence	Prof. Satyajit Das, Prof. Satyadhyan Chickerur, Prof. Bharatkumar Sharma, Prof. Adesuyi Tosin	IIT Guwahati KLE Technological University NVIDIA	12 Weeks	PG
3	noc25-cs108	Software Engineering	Prof. Rajib Mall	IIT Kharagpur	12 Weeks	PG
4	noc25-cs109	Software Project Management	Prof. Rajib Mall, Prof. Durga Prasad Mohapatra	IIT Kharagpur	12 Weeks	PG
5	noc25-cs111	Stochastic Approximation: Theory and Applications	Prof. Gagan Chandrashekhar Mallika Thoppe	IISc Bangalore	12 Weeks	PG
6	noc25-cs115	Computational Complexity	Prof. Subrahmanyam Kalyanasundaram	IIT Hyderabad	12 Weeks	PG
7	noc25-cs116	Cyber Security and Privacy	Prof. Saji K Mathew	IIT Madras	12 Weeks	PG
8	noc25-cs128	Secure Computation: Part II	Prof. Ashish Choudhury	IIIT Bangalore	12 Weeks	PG
9	noc25-cs151	Algorithmic Game Theory	Prof. Palash Dey	IIT Kharagpur	12 Weeks	PG
10	noc25-cs158	Second Level Algorithms	Prof. Palash Dey	IIT Kharagpur	12 Weeks	PG
11	noc25-cs159	Artificial Intelligence: Concepts and Techniques	Prof. V. Susheela Devi	IISc Bangalore	12 Weeks	PG

M.Tech. Computer Science & Engineering (Artificial Intelligence)

Introduction

Artificial Intelligence (AI) based systems have become an essential factor in economic, social development and almost in every facet of our daily lives. AI, deep learning and machine learning are becoming thrust areas and prominent field of study. Professionals who are trained in this field are highly regarded and contribute to strengthening the social, political and financial fabric of modern society.

Program Objectives

The MTech (AI) programme aims at developing Human Resources in the field of AI with a thrust on defence related problems. The present programme is conceived to understand, assimilate & use the advanced technologies to design and develop AI based systems to solve society/ defence problems. Advanced technologies in the areas of deep learning, robotics, machine learning, computer vision, video surveillance, text analytics, speech analytics are the topics/components of this curriculum.

Eligibility: Full-time B.E./B.Tech. in Computer Science/ Electronics/ Electrical/ Electronics & Communications/ Telecommunications/ Information Technology/ Cyber Security/Data Science/AI or equivalent discipline or Full-time M.Sc. in Computer Science/ Mathematics or equivalent discipline with a valid GATE score in- CS, DA, EC, EE, MA, ST, BM, IN. [Computer Science & Information Technology (CS), Data Science & Artificial Intelligence (DA), Electronics & Communication Engineering (EC), Electrical Engineering (EE), Mathematics (MA), Statistics (ST), Biomedical Engineering (BM), Instrumentation Engineering (IN).]

Program Outcome

To generate highly skilled manpower, to research, design, develop and test reliable AI based systems to solve critical problems in various sectors. After completing this course, students are expected to understand and practice the essential concepts related to AI.

Organization

The Programme curriculum has been designed considering the cyber security requirements of Industry and Defence research and development. It is designed and reviewed by panel of experts chosen from various DRDO labs and leading academic institutions. Each subject of 3 credits is delivered by subject experts over the duration of 16 weeks approximately. It consists of 3 hrs. of classroom interaction per week. The evaluations follow a continuous assessment process that includes – 2 intermediate evaluation exams (20 Marks each), an internal assessment (10 Marks), and a final examination (50 Marks). The separate lab course focuses on practical exposure to the AI practicals/hands-on in the form of mini-projects and lab assignments and evaluated as per new PGC guidelines. The 3rd and 4th semesters have a major component of M.Tech. project dissertation of 20 credits each, where the students work under

close supervision and guidance of their project guide. The students present their work at the end of 3rd and 4th semester. The M.Tech. thesis is submitted and evaluated by the panel of expert examiners at the end of the 4th semester.

For 2-year M.Tech.: The M.Tech. programmes will comprise of course work in the first year and research work in the second year. However, the students shall be allowed to opt for (i) only course work in the third and fourth semester or (ii) course work in the third semester and research in the fourth semester or (iii) only research in the third and fourth semester subject to meeting the credit requirements. For I-year M.Tech, Students entering I-year PG after a 4-year UG programme with hon. with research and NEP in the same discipline can choose to do (i) only coursework or (ii) research or (iii) coursework and research meeting the credit requirements of at least 40 credits in a year. For a 2-year M.Tech, students may exit at the end of first year with an additional 3 credits course (CSE allied). Such students should be awarded the degrees as per the current NEP norms (M.Voc{Engg}) exiting at level 6.5 for M. Tech. enrolled students.

Program Educational Objectives (PEOs)

PEO1 The M.Tech. Computer Science and Engineering aims at developing skilled Human Resources in the field of Cyber Security and Artificial Intelligence by providing two different specializations, catering the emerging multidisciplinary problem-solving needs of defense, civil and DRDO sectors.

PEO2 The M.Tech. in Cyber Security(CS) programme aims at developing skilled Human Resources in the field of Cyber Security with a thrust on solving defence and society related problems. The present programme is conceived to understand, assimilate & use the advanced technologies such as Network security, Cryptography, Ethical Hacking, Digital Forensic, Malware Analysis, Information Security Management and Trusted Computing techniques. After completing this course, students are expected to understand and practice the essential CS concepts along with developing secure systems.

PEO3 The M.Tech. Computer Science and Engineering with specialization in Artificial Intelligence programme aims at developing skilled Human Resources in the field of AI with a thrust on solving defence and society related problems. The present programme is conceived to understand, assimilate & apply the advanced technologies such as deep learning, robotics, machine learning, computer vision, video surveillance, text analytics, speech analytics etc. After completing this course, students are expected to understand and practice the essential AI concepts along with developing AI based systems to solve society/defence related problems, carry out research and innovation.

Program Outcomes (PO)

- PO1** The M.Tech. Computer Science and Engineering aims at developing an ability in students to independently carry out research /investigation and development work to solve practical problems
- PO2** The M.Tech. Computer Science and Engineering aims at developing an ability in students to write and present a substantial technical report/document
- PO3** The M.Tech. Computer Science and Engineering students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

Program Specific Outcomes (PSO)

- PSO1** The M.Tech. Computer Science and Engineering aims at developing skillful, knowledgeable Human task force in the field of Cyber Security, catering the needs of defence, social and DRDO requirements
- PSO2** The M.Tech. Computer Science and Engineering aims at developing skillful, knowledgeable Human task force in the field of Artificial Intelligence, catering the needs of defence, social and DRDO requirements.

MTech AI (Artificial Intelligence) Program Structure:

PSC: Program Specific Core PSL: Program Specific Lab PE: Professional Elective

SEMESTER I

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-1	CE-601	Responsible Artificial Intelligence	3	0	3
2	PSC-2	CE-602	Intelligent Algorithms	3	0	3
3	PSC-3	CE-603	Deep Neural Networks	3	0	3
4	PSC-4	CE-604	Practical Machine Learning	3	0	3
5	PE-I		Elective – I (From Department)	3	0	3
6	PSL-I	CE-606L	AI Skill Development Lab	0	3	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total	17	3	20

SEMESTER II

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-5	CE-611	Computer Vision	3	0	3
2	PSC-6	CE- 612	Generative and Adversarial AI	3	0	3
3	PE-II		Elective – II (From Department)	3	0	3
4	PE-III		Elective – III (From Department)	3	0	3
5	PE-IV		Elective – IV	3	0	3
6	PSL-II	CE-607L	AI Advanced Skill Development Lab	0	3	3
7	PGC	PGC-602	Communication Skills & Personality Development	2	0	2
			Total	17	3	20

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	CE-651	M.Tech. Dissertation and Seminar Phase-I	40		20
		Total	40		20

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	CE-652	M.Tech. Dissertation and Seminar Phase-II	40		20
		Total	40		20

List of Audit Courses (Applicable for Sem - II):

Sr.No.	Course Code	Course
9.	PGC-602	English for Research Paper Writing
10.		Disaster Management
11.		Sanskrit for Technical Knowledge
12.		Value Education
13.		Constitution of India
14.		Pedagogy Studies
15.		Stress Management by Yoga
16.		Personality Development through Life Enlightenment Skills

List of Electives/Open Electives (Applicable for Sem - I)

Sr. No.	Course Code	Course
1.	CE606A	Software Engineering & System Modelling
2.	CS-605	Network and Cloud Security
3.	CS-613	Security Standards & Penetration Testing
4.	CE- 613	Large Language Models
5.	CE-613A	Speech and Language Processing
6.	CE-71A	Reinforcement Learning
7.	CE-605	Mathematics for ML
8.	MOOC	Any relevant MOOC course for 3 credits upon

List of Electives/Open Electives (Applicable for Sem - II):

Sr.No.	Course Code	Course
1.	CE 695	Cyber-Physical & Self-Organizing Systems
2.	CE 70G	Blockchain Technology
3.	CE 66A	Algorithmic Cryptanalysis
4.	CE699	Internet of Things
5.	CE 69B	Network Forensics
6.	CE 602A	Computational Intelligence
7.	CE 683	Information Warfare
8.	CE 70A	Formal Specification and Verification of Programs
9.	CE 700	Quantum Computing
10.	CE 70D	Computer Network Audit & Forensics
11.	CE 70E	Machine Learning with Python
12.	CE 70F	Cloud Computing
13.	CE 682	Secure Software Engineering
14.	CE 608	Simulation of Wargames
15.	CE-605	Mathematics for Machine Learning
16.	CE71A	Reinforcement Learning
17.	CE601A	Interpretable and Explainable AI
18.	CE-630	Virtual Reality
19.	CE-633	Pattern Recognition
20.	CE-694	Big Data Analysis and Algorithms
21.	CE- 613A	Speech and Language Processing
22.	MOOC	Any relevant MOOC course for 3 credits upon (Refer Page No.100)
	The electives and other Core Courses offered in the 2 nd semester by the other departments may be opted by the students on consultation with the course OIC/Department.	
	Maximum of 6 Credits can be opted by students as Professional Electives from the	

	list of Online Courses on NPTEL/SWAYAM which are aligned to CSE Domain with During Semester II.

MTECH AI - SEMESTER I CORE COURSES

Subject Code	Course Name	L – T – P	Credits
CE-601	Responsible Artificial Intelligence	3-0-0	03
Course Objectives: The rise of Artificial Intelligence (AI) has brought about unprecedented advancements across various sectors, from healthcare to finance to everyday consumer technology. This subject dwells in concepts of database, data-in-transit, data-at-storage and use of data for decision making in decision support systems. The advancements come with critical challenges. The fairness of AI systems is the need of the hour to study & be able to evaluate. It is essential to ensure that these technologies benefit all individuals and groups without perpetuating or exacerbating existing biases and inequalities			
Course Contents			
Unit I Foundations of Responsible AI- Ethical principles: beneficence, autonomy, justice, accountability - Philosophical frameworks: Utilitarianism, Deontology, Virtue Ethics - Socio-economic impacts of AI (automation, surveillance, inequality) - Value-sensitive design, stakeholder analysis - Global Responsible AI guidelines (OECD, EU AI Act, NITI Aayog)			
Unit II Fairness, Bias, and Causality in AI Types of algorithmic bias: label, representation, sampling - Definitions: group vs. individual fairness - Causal fairness: counterfactuals, DAGs, SCMs, do-calculus - Attacks on fairness models: poisoning, evasion - Real-world cases: hiring, credit scoring, healthcare			
Unit III Transparency, Explainability, and Accountability - Interpretability: global vs. local (LIME, SHAP, Grad-CAM) - Documentation: Datasheets, Model Cards, FactSheets			

- Model and dataset audits - Legal liabilities and institutional accountability in AI failures
Unit IV Adversarial Robustness, Privacy, and Governance - Adversarial threats: FGSM, PGD, black-box/white-box attacks - Defenses: adversarial training, gradient masking - Privacy in ML: differential privacy, federated learning - Causal attacks and perturbations - Global governance: EU AI Act, NIST AI RMF, ISO risk standards - AI for social good: climate, education, health
Course Outcomes
After completing this course, the students will be able to: CO1 Understand ethical, legal, societal, and policy implications of AI systems. CO2 Analyse fairness, bias, transparency, and accountability in AI models using technical tools. CO3 Evaluate AI robustness through adversarial threat modelling and causal inference. CO4 Apply Responsible AI principles in the design of AI systems for critical applications. CO5 Develop leadership and ethical reasoning in AI development with an emphasis on national and societal impacts.
Text Books & Reference Books
1. Barocas, S., Hardt, M., & Narayanan, A. (2019). Fairness and machine learning: Limitations and opportunities (Online draft). Retrieved from https://fairmlbook.org/ 2. Christian, B. (2020). The alignment problem: Machine learning and human values. New York: W. W. Norton & Company. ISBN: 9780393635829. 3. Pearl, J., Glymour, M., & Jewell, N. P. (2016). Causal inference in statistics: A primer. Chichester, UK: Wiley. ISBN: 9781119186847. 4. Vorobeychik, Y., & Kantarcioglu, M. (2022). Adversarial machine learning. San Rafael, CA: Morgan & Claypool Publishers. (Synthesis Lectures on Artificial Intelligence and Machine Learning). ISBN: 9781636393009.
Reference Books
1. O'Neil, C. (2016). Weapons of math destruction: How big data increases inequality and threatens democracy. New York: Crown Publishing Group. ISBN: 9780553418811. 2. Russell, S. (2019). Human compatible: Artificial intelligence and the problem of control. New York: Viking. ISBN (Hardcover): 9780525558613; ISBN (Paperback): 9780141981802. 3. Molnar, C. (2022). Interpretable machine learning: A guide for making black box models explainable (Self-published). Retrieved from https://christophm.github.io/interpretable-ml-book/. ISBN: 9780244768522. 4. Raji, I. D., & Buolamwini, J., Mitchell, M., Gebru, T., & L denton, E. (2020). Model cards for model reporting. In Proceedings of the Conference on Fairness, Accountability, and Transparency (FAT*). ACM. [Also related: Gebru et al., Datasheets for datasets (2018), arXiv:1803.09010]. 5. Kusner, M. J., Loftus, J., Russell, C., & Silva, R. (2017). Counterfactual fairness. In Advances in Neural Information Processing Systems (NeurIPS),

30. [arXiv:1703.06856]

6. Ribeiro, M. T., Singh, S., & Guestrin, C. (2016). "Why should I trust you?": Explaining the predictions of any classifier. In Proceedings of the 22nd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining (KDD), pp. 1135–1144.
7. Kurakin, A., Goodfellow, I., & Bengio, S. (2017). Adversarial examples in the physical world. In Proceedings of the ICLR Workshop. [arXiv:1607.02533]
8. Agarwal, A., & Nene, M. J. (2025). A Five-Layer Framework for AI Governance: Integrating Regulation, Standards, and Certification. Transforming Government: People, Process and Policy.
9. Agarwal, A., Agarwal, H., & Agarwal, N. (2023). Fairness Score and process standardization: framework for fairness certification in artificial intelligence systems. AI and Ethics, 3(1), 267-279.
10. Agarwal, A., & Agarwal, H. (2024). A seven-layer model with checklists for standardising fairness assessment throughout the AI lifecycle. AI and Ethics, 4(2), 299-314.
11. Agarwal, A., & Nene, M. J. (2025). Advancing Trustworthy AI: A Comparative Evaluation of AI Robustness Toolboxes. SN Computer Science, 6(3), 234.

Subject Code	Course Name	L – T – P	Credits
CE-602	Intelligent Algorithms	3-0-0	03
Course Objectives: - To focus on the design, Analysis and Implementation of Intelligent algorithms in various domains - To provide a foundation for designing efficient Intelligent algorithms. - To provide familiarity with main thrusts of work in Intelligent algorithms- Latest developments, diverse applications, Machine Learning, Fuzzy Logic, Genetic Algorithms			
Course Contents			
Unit I Module:1 Algorithm Design Techniques Revisit of Greedy algorithms, divide-conquer, dynamic programming. Backtracking: General method, N-queen problem, Subset sum, Graph coloring, Hamiltonian cycles. Branch and Bound: General method, applications - Traveling sales person problem, 0/1 knapsack problem- LC Branch and Bound solution.			
Unit II Computational Complexity Class complexity classes: P, NP, Reductions, NP-completeness and NP-hard, NP-Complete Problems Textbooks -1			
Unit III Randomized Algorithms Las Vegas algorithms, Randomized Quick Sort, Monte Carlo algorithm, Primality Testing			

Unit IV Algorithms for AI Uninformed search, Heuristic search (8 queen and tiling problems), A* and AO* algorithms, Meta-Heuristics, Stable Matching Algorithm Textbooks -1 Unit V Genetic Algorithms and Evolutionary Computation Introduction, Operators, Applications, GA, ,Swarm Intelligence, Ant Colony Optimization Unit VI Machine Learning Algorithms Supervised/Unsupervised, Decision Trees, Random Forest, Gradient Boosted Trees, XGBM, LGBM, Regression, Classification, Neural Networks, RNN, CNN, Transformers, Greedy algorithms & learning based optimization techniques, Convex Hull in 2D and 3D Textbooks – 2 Unit VII Linear Regression, Clustering, Classification, Metrics, High Performance Multithreading, Parallel Processing, GPU, Linux Clusters, TPU Unit VIII Fuzzy Sets, Fuzzy Logic, Applications, Fuzzy Clustering, K Means Clustering, Fuzzy Logic Control , Fuzzification, Defuzzification, Fuzzy Inferencing Textbooks -2, 3 / References -1-3
Course Outcomes
After completing this course, the students will be able to: CO 1 – Familiarize students with different Intelligent algorithmic techniques CO2: Apply advanced methods of designing and analyzing Intelligent algorithms. CO3: Choose appropriate Intelligent algorithms and use it for a specific problem. CO4: Understand different classes of problems concerning their computation difficulties, Implement Intelligent algorithm, compare their performance characteristics, and estimate their potential effectiveness in applications.
Text Books & Reference Books
1. T.H.Cormen, C.E.Leiserson, R.L.Rivest, and C.Stein, ‘Introduction to algorithms’,4th Edition, MIT Press, 2009. 2. Han Huang, Zhifeng Hao. “Intelligent Algorithms”, 1 st Edition, Elsevier, 2024. 3. Russel and Norvig, “Artificial Intelligence : A Modern Approach”, 4th Ed, Pearson, 2022. 4. R. Hurbans, “Artificial Intelligence Algorithms”, Manning Publishers, 1 st Ed, 2020.
Reference Books
1. M.T.Goodrich and R.Tomassia, ‘Algorithm Design: Foundations, Analysis and Internet examples’ , John Wiley and sons, 2011. 2. A.Levitin, ‘Introduction to the Design and Analysis of Algorithms’, Third Edition, Pearson Education, 2012. 3. Elaine Rich, Kevin Knight, & Shivashankar B Nair, Artificial Intelligence, McGraw Hill, 3rd ed.,2009

Subject Code	Course Name	L – T – P	Credits
CE603	Deep Neural Networks	3-0-0	03
Course Objectives: To understand concepts of Neural Network and Deep Learning. To understand how to train Deep Models and Convolutional Networks. To understanding and analyze the related study and refer different latest research views in Latest trend and techniques.			
Course Contents Unit I Introduction: Overview of machine learning, linear classifiers, loss functions Optimization : Stochastic gradient descent and contemporary variants, backpropagation. Unit II Feedforward networks and training: Activation functions, initialization, regularization, batch normalization, model selection, ensembles. Unit III Convolutional Neural Networks (CNN) : Fundamentals, Architectures, pooling, Visualization, Image Classification and Object Detection using CNN, Inception, Residual Networks, Image Augmentation, Fine Tuning Unit IV Recurrent Neural Networks (RNN) : Fundamentals, Architectures, Long-Short Term Memory (LSTM), Bi-LSTM, Grated Recurrent Unit, Transformers, Attention Sequence-to-Sequence Models and Language Modelling: Language Models, Machine Translation, Image Captioning. Unit V Deep generative models : Auto-encoders, Generative Adversarial Networks, Diffusion Models			
Course Outcomes			
After completing this course, the students will be able to: CO1 Remembering the basics of Neural Network and Deep learning CO2 Understanding the different Neural Network Architectures and Deep Learning Methodologies CO3 Applying different convolution operation, pooling, Functions and sequence modelling			

CO4 Analyze Various other Deep Learning architectures like RNN, Autoencoders and GANs
CO5 Analyzing and gain knowledge about Deep Learning Applications
Text Books & Reference Books
1. Ian Goodfellow, Y. Bengio, A. Courville, Deep Learning, MIT Press, 2016. http://www. deeplearningbook.org. 2. Michael Nielsen, Neural Networks and Deep Learning, Determination Press, 2015. http://neuralnetworksanddeeplearning.com/ 3. Dive into deep learning,A Zhang, ZC Lipton, M Li, AJ Smola - 2023
Reference Books
1. K. P. Murphy, “Probabilistic Machine Learning: An Introduction”, MIT Press, 2022. 2. C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006. 3. A National Initiative on AI Skilling and Research (leadingindia.ai) 4. NPTEL Course Lecture Material: Deep Learning Part-1 By Dr. Mitesh Kapra, IIT Chennai.

Subject Code	Course Name	L – T – P	Credits
CE-604	Practical Machine Learning	3-0-0	03
Course Objectives: • To provide the knowledge of Python programming language as it applies to data analytics. Skills will be developed for Data Analysis with Python and develop products in Python. Student will learn various ML techniques including Supervised, unsupervised classification and regression analysis, Artificial Neural Networks, etc. Student will learn Python Programming for implementing these algorithms on standard datasets			
Course Contents Unit I Data Analytics Foundations: R programming, Python Basics -Expressions and Variables, String Operations, Lists and Tuples, Sets, Dictionaries Conditions and Branching, Loops, Functions, Objects and Classes, Reading/Writing files, Hand ling data with Pandas, Scikit Library, Numpy Library, Matplotlib, scikit programming for data analysis, setting up lab environment, study of standard datasets. Introduction to Machine Learning- Applications of Machine Learning. Unit II Supervised, unsupervised classification and regression analysis, Python libraries suitable for Machine Learning Feature Extraction. Data pre-processing, feature analysis etc., Dimensionality Reduction & Feature Selection Methods, Linear Discriminant Analysis and Principal Component Analysis, tackle data class imbalance problem Supervised and regression analysis, Regression, Linear Regression, Non-linear			

Regression, Model evaluation methods, Classification, K-Nearest Neighbor, Naïve Bayes, Decision Trees, Logistic Regression, Support Vector Machines, Artificial Neural Networks, Model Evaluation. Ensemble Learning, Convolutional Neural Networks, Spectral Embedding, Manifold detection and Anomaly Detection Unit III Unsupervised classification K-Means Clustering, Hierarchical Clustering, Density-Based Clustering, Recommender Systems- Content-based recommender systems, Collaborative Filtering, Unit IV Machine learning techniques for standard dataset, ML applications, Introduction to DL, CNN, Model training, tuning, and Inferencing Case Study: Image spam detection, Face detection, Time series prediction.
Course Outcomes
After completing this course, the students will be able to: CO 1 - Students will be able to understand ML paradigms and various Supervised, unsupervised classification and regression analysis methods. CO2: Students will be able to understand various ML algorithms like and analyse their applications in real world CO3: Students will be able to understand advanced ML algorithms and techniques etc. CO4: Students will be capable of applying their ML knowledge and skills to solve engineering problems in various domains using ML programming languages
Text Books & Reference Books
1. Building Machine Learning Systems with Python - Willi Richert, Luis Pedro Coelho 2. Learning scikit-learn: Machine Learning in Python - Raúl Garreta, Guillermo Moncecchi 3. Machine Learning: An Algorithmic Perspective - Stephen Marsland 4. Sunita Vikrant Dhavale, “Advanced Image-based Spam Detection and Filtering Techniques”, IGI Global, 2017 5. Trevor Hastie, Robert Tibshirani, Jerome Friedman - The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Second Edition. February 2009
Reference Books
1. Stuart Russell, Peter Norvig (2009), “Artificial Intelligence – A Modern Approach”, Pearson Elaine Rich & Kevin Knight (1999), “Artificial Intelligence”, TMH, 2nd Edition 2. NP Padhy (2010), “Artificial Intelligence & Intelligent System”, Oxford 3. ZM Zurada (1992), “Introduction to Artificial Neural Systems”, West Publishing Company 4. Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/ NVidia sources.

Subject Code	Course Name	L – T – P	Credits
CE 606L	AI Skill Development Lab – Semester 1	3-0-0	03
Course Objectives: • To impart hands on knowledge of basic AIML-DL experiments. • To introduce the experimental approach of subject. • To enable the students to understand the hands-on experience of various AI/ML/DL concepts.			
Course Contents			
Unit I C++ Programming.			
Unit II Python programming.			
Unit III SQL.			
Unit IV CUDA programming.			
Unit V Project in above four points..			
Unit VI Implementation of foundational concepts of supervised learning. Will include-linear regression, logistic regression, support vector machines, decision trees.			
Unit VII Implementation of foundational concepts of supervised learning. Will include-linear regression, logistic regression, support vector machines, decision trees.			
Unit VIII Implementation of foundational concepts of unsupervised learning. Clustering techniques- K-means; hierarchical clustering and DBSCAN. Duration one week.			
Unit IX Implementation of foundational concepts of unsupervised learning. Clustering techniques- dimensionality reduction- PCA, t-distributed stochastic neighbour embedding, auto encoders.			
Unit X Experiments on (1) anomaly detection & (2) association rule learning techniques.			
Unit XI Experiments on techniques to estimate density. Ex. Gaussian mixture models, Kernel density estimation.			
Unit XII Cloud based AI model training and deployment			
Course Outcomes			
CO1: Students will be able to understand and apply image processing techniques including filtering operations, thresholding techniques, edge detection techniques etc. CO2: Students will be able to understand and extract image features using techniques			

like corner and interest point detection, shape analysis, fourier descriptors, Ransac, GHT etc.

CO3: Students will be able to understand and learn how the extracted features can be used to solve problems in various computer vision related applications. CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in computer vision related domain.

Text Books & Reference Books

1. Python/scikit/tensorflow/keras/matplotlib programming Resources

MTECH AI - SEMESTER II CORE COURSES

Subject Code	Course Name	L – T – P	Credits
CE-611	Computer Vision	3-0-0	03
Course Objectives: • To introduce students the fundamentals of image formation; To introduce students the major ideas, methods, and techniques of computer vision and pattern recognition; To develop an appreciation for various issues in the design of computer vision and object recognition systems; and To provide the student with programming experience from implementing computer vision and object recognition applications.			
Course Contents Unit I Image processing foundations: Review of image processing techniques, classical filtering operations, thresholding techniques, Noise removal Operations, Color Models, edge detection techniques – canny edge detection, introduction to packages -python, opencv, pytorch, tensorflow, matplotlib, scikit, pandas etc. Linear algebra basic concepts Unit II mathematical morphology, texture analysis, Shapes and regions: Binary shape analysis – connectedness – object labeling and counting –distance functions, boundary descriptors – chain codes, Fourier descriptors – region descriptors – moments, Corner and interest point detection, SIFT, Interest Feature detection Unit III Hough transform, GHT for ellipse detection – object location – GHT for feature collation RANSAC for straight line detection – HT based circular object detection, Introduction to Deep Learning, CNN for Image classification and CV applications, Region-based CNN (R-CNN) and You Only Look Once (YOLO) for Object Detection, Image segmentation, Unit IV Introduction to RCNN, transformers and diffusion models, vision transformers etc. Case Study: Image based spam detection, Case Study: CV Applications - Face detection – Face recognition – Eigen faces, Case Study: CV Applications - human gait analysis, Case Study: CV based Surveillance Applications, Stereo Vision concepts, Case			

Study: CV in Underwater marine applications, case study on multi-modal input data analysis, Case Study: image captioning
Text Books
1. Forsyth, David Computer vision a modern approach, 2nd, Pearson, 2015 2. R. Szeliski, "Computer Vision: Algorithms and Applications", 2nd ed. 2022., Springer 3. Foundations of Computer Vision (Adaptive Computation and Machine Learning series) Hardcover – Import, 16 April 2024 by Antonio Torralba (Author), Phillip Isola (Author), William T. Freeman (Author) he MIT Press (16 April 2024) 4. Goodfellow, Ian, Deep learning The MIT Press. 2015
Reference Books
1. Hands-on ML Projects with OpenCV: Master computer vision and Machine Learning using OpenCV and Python Paperback – Import, 9 August 2023 by Mughesh S. (Author). 2. Sunita Vikrant Dhavale, "Advanced Image-based Spam Detection and Filtering Techniques", IGI Global, 2017 3. Research paper for study (if any)-White papers on multimedia from IEEE/ACM/Elsevier/Spinger/ NVidia sources.

Subject Code	Course Name	L – T – P	Credits
CE612	Generative and Adversarial AI	3-0-0	03
Course Objectives: • Understand the concepts and needs of Generative modelling and learn the concepts of Auto-Regressive Models, Variational Auto Encoders, Diffusion Models. Implement the learned concepts to generate the data related to specific applications of image and Video. Explore ethical considerations, including bias, misinformation, adversarial attacks and Future Trends.			
Course Contents Unit I Generative Modelling, Maximum Likelihood Estimation, Taxonomy of Deep Generative Models, Explicit and Implicit Density Models. Generative Adversarial Networks (GANs): Architecture of GANs: Generator and Discriminator; Training Process, Challenges, and Variants (DCGAN, StyleGAN); Applications of GANs: Image Generation, Style Transfer, Data Augmentation, Super-Resolution. Unit II Auto-Encoder Models: Basics of Auto-Encoder Models, Motivation, Activation and Loss functions, Training process for Auto-Encoders Types of Auto-Encoder Models: Sparse Auto-Encoders, Denoising Auto-Encoders, Contractive Auto-Encoders, Deep Auto-Encoders. Masked Autoencoder for Distribution Estimation (MADE) Applications of Auto-Encoders: Dimensionality Reduction, Anomaly Detection, Semantic Ha shing, Image Processing.			

Unit III Variational Auto-Encoders (VAEs): Explicit Density Generative Modelling, Basics of VAE, Training, Loss function, Reparameterization trick, Applications. Diffusion Models: Forward and Reverse Diffusion Processes, Noise Scheduling Applications of Diffusion Models: Image Generation, Text-to-Image Synthesis, Audio Generation Unit IV Adversarial attacks against Deep Generative models: Types of attacks, Threat models, Defence tactics. Ethical Implications: Bias and Fairness, Misinformation and Deepfakes; Responsible Gen AI Development and Deployment Future Trends: Multimodal Generative AI, Reinforcement Learning for Generative Models; Explainable AI and Interpretability for Generative Models
Course Outcomes
After completing this course, the students will be able to: CO1 Remembering the basics of Generative Modelling CO2 Understanding the different types of Generative Models, Auto-Encoder Models, Variational Auto-Encoders and Diffusion Models CO3 Applying different GAN architectures for Image and Video Data. Explore Ethical Implications and Future Trends CO4 Analyze and Demonstrate Various GAN architectures for different applications
Text Books
1. Tutorial on Generative Adversarial Networks. Ian Goodfellow. Neural Information Processing Systems, December 2016. 2. Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play, 1st Edition, David Foster, 2019 3. Zhou, M.; Abhishek, V.; Derdenger, T.; Kim, J.; Srinivasan, K. Bias in Generative AI. arXiv 2024, arXiv:2403.02726. 4. Zhang C. Yu S. Tian Z. Yu J. J. (2023). Generative adversarial networks: A survey on attack and defense perspective. ACM Computing Surveys, 56(4), 1–35. 10.1145/3615336 5. Adversarial attacks against deep generative models on data: A survey H Sun, T Zhu, Z Zhang, D Jin, P Xiong, W Zhou, IEEE Transactions on Knowledge and Data Engineering, 2021
Reference Books
1. Goodfellow, Y. Bengio, A. Courville, Deep Learning, MIT Press, 2016. http://www. deeplearningbook.org. 2. NPTEL Course Lecture Material: Deep Learning Part-II By Dr. Mitesh Kapra, IIT Chennai.

Subject Code	Course Name	L – T – P	Credits
CE 607L	AI Advanced Skill Development Lab – Semester 2	3-0-0	03
Course Objectives: • To impart hands on knowledge of basic AIML-DL experiments. • To introduce the experimental approach of subject. • To enable the students to understand the hands-on experience of various AI/ML/DL concepts.			
Course Contents Unit I • Preliminary- Hands-on session for Kali Linux and Windows training for 10 hours each. 05 Hours for basics of HPC. • Machine Learning Foundations • Deep Learning Core Concepts • Computer Vision Techniques • Natural Language Processing Models Unit II • Reinforcement Learning Algorithms • Explainable AI and Ethical AI • Advanced AI Model Deployment (DevOps + Cloud) Unit III • Generative Modeling • Optimization and Hyperparameter Tuning • Multimodal AI Systems • AI Governance, Ethics, and Bias Handling			
Course Outcomes			
After completing this course, the students will be able to: CO1 Remembering the basics of Mathematical Machine Learning CO2 Understanding various domains of Mathematical Machine Learning CO3 Applying different concepts of Linear Algebra, Probability, Optimization and Dimensionality Reduction for Practical Problems CO4 Analyze Mathematical Machine Learning based Models and fine tune them for real datasets.			
Text Books			
1. Python/scikit/tensorflow/keras/matplotlib programming Resources			

Reference Books

1. Deep Learning – Ian Goodfellow, Yoshua Bengio, Aaron Courville, <https://www.deeplearningbook.org>;
2. Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow – Aurélien Géron; Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems, Third Edition Grokking Deep Learning – Andrew Trask
3. Publisher. Manning ; Publication date. 25 January 2019 ; Dimensions. 18.75 x 1.78 x 23.5 cm ; ISBN-10. 1617293709 ; ISBN-13. 978-1617293702.
4. Reinforcement Learning: An Introduction – Richard S. Sutton, Andrew G. Barto, <https://web.stanford.edu/class/psych209/Readings/SuttonBartoIPRLBook2ndEd.pdf>
5. Natural Language Processing with Python – Steven Bird, Ewan Klein, Edward Loper, <https://www.nltk.org/book/>
6. Pattern Recognition and Machine Learning – Christopher M. Bishop; <https://link.springer.com/book/9780387310732>

SEMESTER I/II ELECTIVE COURSES

Subject Code	Course Name	L – T – P	Credits
CE-605	Mathematics for Machine Learning	3-0-0	03
Course Objectives: • Machine Learning refers to the automated identification of patterns in data. As such it has been a fertile ground for new statistical and algorithmic developments. The purpose of this course is to provide a mathematically rigorous introduction to these developments with emphasis on methods and their analysis			
Course Contents			
Unit I			
Linear Algebra and Matrix Decomposition: Scalars, Vectors, Matrices and Tensors, Multiplying Matrices and Vectors, Identity and Inverse Matrices – Linear Dependence and Span – Norms – Special kinds of matrices and vectors – Determinant and Trace, Eigenvalues and Eigenvectors, Cholesky Decomposition, Eigen decomposition and Diagonalization , Singular Value Decomposition, Matrix Approximation, Differentiation of Univariate Functions, Partial Differentiation and Gradients, Gradients of Vector-Valued Functions, Gradients of Matrices, Useful Identities for Computing Gradients			
Unit II			
Probabilistic Machine Learning: Fundamentals of Probability, Univariate and Multivariate Models, Joint Distributions, Bayesian Statistics and Regularization Methods, Decision and Information Theory.			
Unit III			

Optimizations: Introduction to Optimization methods, first and second order optimization, Stochastic gradient descent, Constrained Optimization, Black box and derivative free optimization. Unit IV Dimensionality Reduction with Principal Component Analysis: Problem Setting, Maximum Variance Perspective, Projection Perspective, Eigenvector Computation and Low-Rank Approximations, PCA in High Dimensions, Key Steps of PCA in Practice, Latent Variable Perspective, Analyzing Mathematical Machine Learning based Models and fine tuning them for real datasets	
Course Outcomes	
After completing this course, the students will be able to: CO1 Remembering the basics of Mathematical Machine Learning CO2 Understanding various domains of Mathematical Machine Learning CO3 Applying different concepts of Linear Algebra, Probability, Optimization and Dimensionality Reduction for Practical Problems CO4 Analyze Mathematical Machine Learning based Models and fine tune them for real datasets.	
Text Books	
1. “Mathematics for Machine Learning”, By Marc Peter Deisenroth, A. Aldo Faisal, Cheng Soon, Cambridge University Press, 2020 2. “Probabilistic Machine Learning: An Introduction”, By Kevin P. Murphy, The MIT Press Cambridge, Massachusetts London, England, 2022	
Reference Books	
1. https://mltechniques.com/2022/06/13/math-for-machine-learning-12-must-read-books/ Model-Based Machine Learning, By John Winn, CRC Press, 2023.	

Subject Code	Course Name	L – T – P	Credits
CE-613	Large Language Models	3-0-0	03
Course Objectives: This course is intended to prepare the students for performing cutting-edge research in Large Language Models, especially topics related to pre-trained language models by understanding the state-of-the-art models, their capabilities, and limitations. The course captures essential aspects of LLMs such as Pretraining, Fine Tuning, Alignment, RAG, Agents, Applications, Evaluation, Performance enhancement, Quantization, Distillation, etc.			
Course Contents			
Unit I Introduction, Evolution of LLMs, Scaling Laws An Overview of NLP and Neural Networks, NLP pipeline, Morphology, Tokenisation, Syntactics, Semantics, Neural Networks, Multilayer Perception, Training NNs, Backpropagation, Evaluation Metrics Word Embedding, Vector Semantics Types of Word Embedding, Word2vec, Glove, FastText, Limitations, Applications			

Statistical Language Modeling, Smoothing, Evaluation of Language Models, Limitations, Neural Language Models, CNN, RNN, Sequence To sequence Models, Attention Mechanisms Transformers, Self-Attention, Transformer Encoder, Decoder, Positional Embeddings Unit II Language model Pretraining, Embeddings, Evaluation Datasets, Encoder-based, Decoder-based, Encoder-decoder-based, LLMs, Limitations Fine Tuning and Alignment Finetuning on various task specific applns, Instruction Tuning, Alignment Methods, Reinforcement Learning from Human Unit III Prompting strategies for LLMs, Prompt Engineering, Chain of Thoughts, Tree of Thoughts, Graph of Thoughts, Efficient Methods of Fine Tuning, Distillation, Model Compression, PEFT, Mixed Precision Tuning Augmented LLMs, RAGs, Evaluation of RAGs, Tool Calling in LLMs, Agents Unit IV Multilingual and Multimodal LLMs, Training, Challenges, Responsible LLMs, Bias, Mitigation Advanced Topics in LLMs, Reasoning, Handling Long Context, Model Editing, Hallucination, Self-Evolving LLMs in Action, Panoramic View of LLMs, Diverse Applications, Emerging Trends and Future Directions			
Course Outcomes			
After completing this course, the students will be able to: CO1 Remembering the Probabilistic theory of LLMs, NLP, ANN, Word Embeddings, CNN, RNN, Statistical Models, Neural Models, Transformers CO2: Understanding Modelling , Pretraining, Fine Tuning, LoRA, Alignment, RLHF CO3: Applying Transfer Learning for Training, Parameter Efficient Fine Tuning and Inference of LLMs, Prompt Engineering, RAG, Agent LLM CO4: Analyse LLMs for Security & AI Safety, Multilingual and Multimodal LLMs, Long Context, Evaluation Benchmarks, Applications			
Text Books			
1. T. Chakraborty, “Introduction to Large Language Models”, Wiley, 2025 2. S.Bird, E Klein and E Loper, —Natural Language Processing with Pythonll.O’Reilly, 2009.			
Reference Books			
1. Deep Learning (deeplearningbook.org) 2. Introduction to Natural Language Processing (Eisenstein) 3. COS 597G: Understanding Large Language Models (princeton.edu)			

Subject Code	Course Name	L – T – P	Credits

CE-613A	Speech and Language Processing	3-0-0	03
Course Objectives: This course is intended to prepare the students for performing cutting-edge research in natural language processing, especially topics related to pre-trained language models by understanding the state-of-the-art models, their capabilities, and limitations.			
Course Contents			
Unit I Introduction to Speech and Audio signal Processing, introduction to speech/audio features like mfcc, spectrograms, Language Processing with Python, Accessing Text Corpora, Conditional Frequency Distribution, Lexical Resources. Categorizing and Tagging Words, Tagger, Tagged Corpora, Automatic Tagging, NGram Tagging, Transformation based Tagging, Learning to classify Text, Supervised Classification, Evaluation, Decision Trees, Naïve Bayes Classifier, Maximum Entropy Classifiers, Extracting Information from Text, Information Extraction, Chunking, Evaluation of Chunking, Recursion, Relation			
Unit II Introduction and Overview; Probabilistic Foundations: Basic Measure Theory, Defining a Language Model, Tight Language Models, The Language Modeling Task, Modeling Foundations: Finite-State Language Models, Recurrent Neural Language Models			
Unit III Neural Network Modeling: Representational Capacity of RNN LMs, Transformer-based Language Models, Transformer-based Language Models, Representational Capacity of Transformer-based Language Models, Tokenization, Generating Text from a Language Model			
Unit IV Training, Fine Tuning and Inference: Transfer Learning, Parameter efficient finetuning, In- context learning, Prompting, zero-shot, instruction tuning Applications and the Benefits of Scale: Multimodality, Retrieval augmented Language Models			
Unit V Introduction to ChatGPT, Introduction to Speech and Language Processing			
Course Outcomes			
After completing this course, the students will be able to: CO1 Remembering the Speech and Audio signal and language Processing CO2 Understanding Modeling Foundations and Neural Network Models for Language Models CO3 Applying Transfer Learning for Training, Fine Tuning and Inference of LMs CO4 Analyze applications of LMs			

Text Books
1. Large Language Models, Spring 2023 Rycolab LLM Course Notes Part 1 2. LLM Course Notes Part 2 3. S.Bird, E Klein and E Loper, —Natural Language Processing with Pythonl, O'Reilly,2009. 4. Speech and Language Processing” (Aug 2024 online version) by Daniel Jurafsky and James Martin
Reference Books
1. Deep Learning (deeplearningbook.org) 2. Introduction to Natural Language Processing (Eisenstein) 3. COS 597G: Understanding Large Language Models (princeton.edu)

Subject Code	Course Name	L – T – P	Credits
CE-630	Virtual Reality	3-0-0	03
Course Objectives: • To impart fundamental knowledge of Virtual Reality systems, including their core concepts, components, and architecture. • To familiarize students with the hardware and software technologies used in creating and experiencing Virtual Reality. • To enable students to understand the principles of human perception (visual, auditory, vestibular) and their implications in VR design. • To equip students with the ability to analyze interaction techniques and evaluate VR applications. • To introduce students to current trends, applications, and ethical considerations in VR/AR/MR fields.			
Course Contents Unit I Introduction, Definition, Applications Bird’s Eye View, Hardware, Software, Human Physiology and Perception Geometry of Virtual Worlds, Geometric models, Viewing Transformations, Chaining Transformations Unit II Light and Optics, Lenses, optical aberrations, Human Eye, Cameras, displays Physiology of Human Vision: Cornea, Photoreceptors, Eye Movements, Implications for VR Visual Perception: Perception of Depth, Perception of Motion, Perception of Color, Combining sources of information Unit III Visual Rendering: Ray tracing and Shading models, Rasterization, Correcting optical distortions, Improving latency and frame rates, Immersive photos and videos Motion in Real and Virtual Worlds: Velocities and accelerations, Vestibular system, Physics in virtual world, Mismatched motion and vection Tracking: Tracking in 2D, Tracking in 3D, Tracking position and orientation, Tracking attached bodies, 3D scanning of environment Unit IV Interaction: Motor programming and remapping, Locomotion and manipulation, social interaction and other interaction mechanisms Audio: Physics and sound, physiology of human hearing, Auditory perception, Auditory hearing Evaluation of VR Systems and			

Experiences: Perceptual training, recommendation for developers, Comfort and VR Sickness, Experiments on Human Subjects Frontiers: Touch and Proprioception, Smell and taste, Robotic interfaces and Brain machine interfaces			
Course Outcomes			
After completing this course, the students will be able to: CO 1 – Students will be able to understand and apply Virtual Reality Concepts along with various applications. CO2: Students will be able to understand and apply Virtual Reality concepts, hardware, software, standards and policies required for various applications. CO3: Students will be able to analyze the implementation of Virtual Reality Systems, including their applications, benefits, and limitations. CO4: Students will be able to analyze and propose solutions for engineering problems in Virtual Reality by applying acquired knowledge and skills.			
Text Books			
1. Steven Lavallo, “Virtual Reality”, Cambridge University Press, (lavallo.pl/vr/book.html), 2020. 2. Handbook of Virtual Environments: Design, Implementation, and Applications, Third Edition edited by Kelly S. Hale and Kay M. Stanney (CRC Press, 2021)			
Reference Books			
1. Practical Augmented Reality: A Guide to the Technologies, Applications, and Human Factors for AR and VR (Usability) by Steve Aukstakalnis (Addison-Wesley Professional, 2nd Edition, 2022) 2. The VR Book: Human-Centered Design for Virtual Reality by Jason Jerald (ACM Books / Morgan & Claypool, 2015) 3. Unity 2022 Virtual Reality Projects - Third Edition by Jonathan Linowes (Packt Publishing, 2022)			
Subject Code	Course Name	L – T – P	Credits
CE-70G	Blockchain Technology	3-0-0	03
Course Objectives: • Blockchain is an emerging technology platform for developing decentralized applications and data storage, The basic tenet of this platform is that it allows one to create a distributed and replicated ledger of events, transactions, and data generated through various IT processes with strong cryptographic guarantees of tamper resistance, immutability, and verifiability. The technology itself holds much more promise in various areas such as time stamping, logging of critical events in a system, recording of transactions, trustworthy e-governance etc. Many researchers are working on many such use cases such as decentralized public key infrastructure, self-sovereign identity management, registry maintenance, health record management, decentralized authentication, decentralized DNS, etc. Considering the need to disseminate the emerging concepts for students, we proposed a new course on blockchain technology, includes the fundamental design and architectural primitives of Blockchain, the			

system and the security aspects, along with various use cases from different application domains

Course Contents

Unit I

Basic Cryptographic primitives used in Blockchain – Secure, Collision-resistant hash functions, digital signature, public key cryptosystems, zero-knowledge proof systems

Unit II

Centralized Systems, Basic Distributed System concepts – distributed consensus and atomic broadcast, Double Spend Attack, Race Condition, Byzantine fault-tolerant consensus methods.

Unit III

Basic Blockchain – concepts to Bitcoin and contemporary, Puzzle friendliness, proof-of-work based consensus mechanisms, Merkle Trees, Proof of membership, operations of Bitcoin blockchain, crypto-currency as application of blockchain technology, Bitcoin Scripts. Applications of Bitcoin Scripts.

Unit IV

Ethereum Blockchain: Smart Contract, Introduction to Solidity Language, Proof of stake, Ethereum Network, Programme execution with EVM.

Unit V

Hyperledger fabric platform- Decomposing the consensus process, Hyperledger fabric components, Chaincode Design and Implementation of Hyperledger Fabric

Unit VI

IoTA : Formation of Tangle, Cumulative weight, Consensus in IoTA, Double Spending Attack.

Beyond Cryptocurrency – applications of blockchain in cyber security, integrity of information, E- Governance and other contract enforcement mechanisms. Research Aspects in Blockchain

System sequence diagrams (SSD) -Relationship between sequence diagrams and use cases Logical architecture and UML package diagram, Logical architecture refinement, UML class diagrams, UML interaction diagrams

Course Outcomes			
After completing this course, the students will be able to: CO 1 : Students will be able to Understand cryptographic and distributed system principles foundational to blockchain security CO2: Students will be able to design and implement decentralized applications using blockchain platforms like Ethereum and Hyperledger CO3: Students will be able to Evaluate novel consensus models and blockchain applications in emerging domains like IoT and e-Governance CO4: Students will be able to explore current trends, challenges, and research directions in blockchain security			
Text Books			
1. Software Engineering- Pankaj Jalote, TMH Software Engineering- Ian Sommerville , Pearson Craig Larman, "Applying UML and Patterns: An Introduction to object-oriented Analysis and Design and iterative development", Third Edition, Pearson Education			
Reference Books			
1. Bitcoin and Cryptocurrency Technologies by Arvind Narayanan, Joseph Bonneau, Edward Felten, Andrew Miller, Steven Goldfeder, Princeton University Press 2. "S. Shukla, M. Dhawan, S. Sharma, S. Venkatesan, 'Blockchain Technology: Cryptocurrency and Applications', Oxford University Press. 3. Josh Thompson, 'Blockchain: The Blockchain for Beginnings, Guild to Blockchain Technology and Blockchain Programming', Create Space Independent Publishing Platform James W-Cooper, Addison- Wesley, "Java Design Patterns-A Tutorial", Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides, "Design patterns: Elements of Reusable object-oriented software", - Addison-Wesley.			
Subject Code	Course Name	L – T – P	Credits
CE 66A	Algorithmic Cryptanalysis	3-0-0	03
Course Objectives:			
This course discusses cryptanalysis from basics to advanced application from algorithmic point of view. After completion of the course, the students should be able to identify and apply the suitable algorithm for more sophisticated cryptographic applications, including LFSR-based stream ciphers and index calculus methods. The students should be able to observe the advancements in current computer architectures and its impact on implementation aspects of cryptanalysis methods.			
Course Contents			
Unit I			

Preliminaries, Defining security in cryptography, Elementary Number Theory and Algebra, Evolution in Computing Devices, Evolution in Communication Media, Evolving Programming Environments, Three Generic Forms of Cryptanalysis: Cipher text only, Known cipher text/plain text pairs, and Chosen plain text or

chosen cipher text.

Unit II

General Approaches to Cryptanalysis – (i) based on properties on encryption algorithms & (ii) brute force, Linear Algebra, Sieve Algorithms, Brute Force Cryptanalysis, The Birthday Paradox: Sorting or Not? Birthday-Based Algorithms

for Functions, Algorithmic complexities & computational costs.

Unit III

Birthday Attacks through Quadrisection, Fourier and Hadamard–Walsh Transforms, Lattice Reduction, Polynomial Systems and Gröbner Bases Computations; Study of protocols for cryptanalysis.

Unit IV

Attacks on Stream Ciphers, Lattice-Based Cryptanalysis, Elliptic Curves and Pairings, Index Calculus Algorithms

Text Books

1. Algorithmic Cryptanalysis, by Antoine Joux, 2010

Reference Books

1. Big Data Fundamentals: Concepts, Drivers & Techniques (Prentice Hall Service Technology) Paperback – Import, 5 Jan 2016 by Thomas Erl (Author), Wajid Khattak (Author), Paul Buhler (Author), Publisher: Prentice Hall (5 January 2016), 240 pages , ISBN-10: 0134291077 , ISBN-13: 978-0134291079
2. Big Data: Concepts, Technology, and Architecture, Balamurugan Balusamy, Nandhini Abirami R, Seifedine Kadry, Amir H. Gandomi, Wiley Publications, ISBN: 978-1-119-70185- 9 March 2021

Subject Code	Course Name	L – T – P	Credits
CE 699	Internet of Things - Elective	3-0-0	03
Students will acquire an understanding of the fundamental concepts for developing IoT devices and software configuration required for IoT implementations.			
Course Contents			

Unit I

Introduction to Internet of Things, Definition and Characteristics of IoT, Physical Design of IoT, IoT Protocols, IoT communication models, IoT Communication APIs

Unit II

IoT enabling Technologies, Wireless Sensor Networks, Cloud Computing, Big data analytics, Communication protocols, Embedded Systems, IoT Levels and Deployment Templates, Domain Specific IoTs: Home, City, Environment, Energy, Retail, Logistics, Agriculture, Industry, health and Lifestyle

Unit III

IoT and M2M, Software defined networks, network function virtualization, difference between SDN and NFV for IoT, Basics of IoT System Management with NETCOZF, YANG, NETCONF, YANG, SNMP NETOPEER

Unit IV

IoT physical end devices & end points, IoT Physical Servers & Cloud offerings, Software environments, NEO, Security

Text Books & Reference Books

1. "Internet of Things: A Hands-on Approach", by Arshdeep Bahga and Vijay Madisetti (Universities Press), 2014
2. "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by Pethuru Raj and Anupama C. Raman (CRC Press)
3. "Designing the internet of things", McEwen, Adrian, and Hakim Cassimally. John Wiley & Sons, 2013.
4. Research Papers discussed in the classroom discussions.

Subject Code	Course Name	L – T – P	Credits
CE 633	Pattern Recognition - Elective	3-0-0	03

Course Objectives:

- Students will acquire an understanding of the fundamental concepts of pattern recognition techniques.

Course Contents**Unit I:****Basics of Probability, Random Processes and Linear Algebra (recap):**

Probability: independence of events, conditional and joint probability, Bayes theorem Random Processes: Stationary and non-stationary processes, Expectation, Autocorrelation, Cross- Correlation, spectra.

Unit II:

Linear Algebra: Inner product, outer product, inverses, eigen values, eigen vectors, singular values, singular vectors.

Unit III:

Bayes Decision Theory : Minimum-error-rate classification. Classifiers, Discriminant functions, Decision surfaces. Normal density and discriminant functions. Discrete features.

Unit IV:

Parameter Estimation Methods: Maximum-Likelihood estimation :Gaussian case. Maximum a Posteriori estimation. Bayesian estimation: Gaussian case. Unsupervised learning and clustering - Criterion functions for clustering. Algorithms for clustering: K- Means, Hierarchical and other methods. Cluster validation. Gaussian mixture models, Expectation-Maximization method for parameter estimation. Maximum entropy estimation. Sequential Pattern Recognition. Hidden Markov Models (HMMs). Discrete HMMs. Continuous HMMs. Nonparametric techniques for density estimation. Parzen- window method. K-Nearest Neighbour method.

Unit V:

Dimensionality reduction: Principal component analysis - it relationship to eigen analysis. Fisher discriminant analysis - Generalised eigen analysis. Eigen vectors/Singular vectors as dictionaries. Factor Analysis, Total variability space - a dictionary learning methods. Non negative matrix factorisation - a dictionary learning method.

Unit VI:

Linear discriminant functions : Gradient descent procedures, Perceptron, Support vector machines - a brief introduction.

Unit VII:

Artificial neural networks: Multilayer perceptron - feedforwark neural network. A brief introduction to deep neural networks, convolutional neural networks, recurrent neural networks.

Unit VIII:

Non-metric methods for pattern classification : Non-numeric data or nominal data. Decision trees: Classification and Regression Trees (CART).

Course Outcomes

After completing this course, the students will be able to:

CO1: Student will be able to examine and identify Data Models for various applications

CO2: Student will be able to apply data abstraction & normalisation techniques to handle volume and veracity

CO3: Student will be able to analyze & apply multi-dimensional data models for complex scenarios **CO4:** Student will be able to evaluate the system requirements and propose solutions using various data models to cater special application requirements & to form a base to apply Data Mining & AIML techniques.

Text Books & Reference Books

1. R.O.Duda, P.E.Hart and D.G.Stork, Pattern Classification, John Wiley, 2001
2. S.Theodoridis and K.Koutroumbas, Pattern Recognition, 4th Ed., Academic Press, 2009
3. C.M.Bishop, Pattern Recognition and Machine Learning, Springer, 2006

Subject Code	Course Name	L – T – P	Credits
CE694	Big Data Analysis & Algorithms	3-0-0	03
Course Objectives: Major objective is to learn basic principles of Software Engineering and Design, which can facilitate the resource efficient model of the Software Systems.			
Course Contents Unit I Introduction to big data analysis: Evolution of data, data streams, database models, graph data, normalizations, structured & unstructured data, Unit II Architectures, Adoption, Frameworks that enable big data analytics, Multi-Dimensional Data Models, Data cube Computations Unit III Data Preprocessing, Data Warehousing OLTPS, OLAPS, Data Warehouse Architectures, Big Data Mining Frequent Patterns, Big Data Associations & Correlations, Classifications & Predictions, Clustering Techniques & Analysis, Mining Data Streams, Graph Mining, Mining Spatial & Temporal Objects, Predictive Analysis, Ad Hoc Queries, Web Analytics Unit IV Algorithms for SISD, SIMD environments, Linked Big Data Analysis – Graph Computing and Network Science, Big Data Visualization, Big Data Mobile Applications, Large-Scale Machine Learning, Big Data Analytics on Specific Processors, Hardware and Cluster Platforms for Big Data Analytics, Big Data Next Challenges – IoT, Cognition, and Beyond			

Unit V

Big Data Storage & Processing Concepts Relational database technology, Parallel and Distributed Processing capabilities, Clouds, Map Reduce Framework

Unit VI

Database Auditing Models Technical Audit Environment, Process, Objectives, Classification Types, Incidence Reports, Level of escalations.

Application Data Audit:

DML Action Audit; Triggers; Fine-Grained Auditing FGA; Application Errors; PL-SQL Environments, Audit

DB Activities

Unit VII

Big data analytics tools, HDFS, NOSQL, SQL environments Project Cases Big data, Big Data Security: Online Databases; CSV files to Structured Environments, SCADA, IoTs,

Course Outcomes

After completing this course, the students will be able to:

CO1: Student will be able to examine and identify Data Models for various applications

CO2: Student will be able to apply data abstraction & normalisation techniques to handle volume and veracity

CO3: Student will be able to analyze & apply multi-dimensional data models for complex scenarios **CO4:** Student will be able to evaluate the system requirements and propose solutions using various data models to cater special application requirements & to form a base to apply Data Mining & AIML techniques.

Text Books

1. Big Data Fundamentals: Concepts, Drivers & Techniques (Prentice Hall Service Technology) Paperback – Import, 5 Jan 2016 by Thomas Erl (Author), Wajid Khattak (Author), Paul Buhler (Author), Publisher: Prentice Hall (5 January 2016), 240 pages , ISBN-10: 0134291077 , ISBN-13: 978-0134291079
2. Big Data: Concepts, Technology, and Architecture, Balamurugan Balusamy, Nandhini Abirami R, Seifedine Kadry, Amir H. Gandomi, Wiley Publications, ISBN: 978-1-119-70185- 9 March 2021

Reference Books

1. Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006

Subject Code	Course Name	L – T – P	Credits
CE 71A	Reinforcement Learning	3-0-0	03
Course Objectives:			

Reinforcement learning is a paradigm that aims to model the trial-and-error learning process that is needed in many problem situations where explicit instructive signals are not available. It has roots in operations research, behavioral psychology and AI. The goal of the course is to introduce the basic mathematical foundations of reinforcement learning, as well as highlight some of the recent directions of research.
Course Contents Unit I Introduction to reinforcement learning (RL), RL vs AI/non-interactive machine learning approaches Model problems as Markov decision processes (MDP), evaluate and optimize policies using dynamic programming, Monte Carlo methods, and temporal difference (TD) learning, Techniques for approximating value functions and policies, linear and nonlinear value function approximation and policy gradient methods. Unit II - Distributed RL, - Explore the AlphaZero algorithm and how it was able to beat professional Go players - Bandit algorithms – UCB, PAC, Median Elimination, Policy Gradient - Bellman Optimality Unit III - Dynamic Programming - Eligibility Traces - Function Approximation - Least Squares Methods Unit IV - Q Learning, Deep DQN & Policy Gradient for Full RL - Hierarchical RL - Actor-Critic Methods - Safe RL - Multi-Agent RL - Real world RL applications/frameworks like Unity ML-Agents etc.
Course Outcomes After completing this course, the students will be able to: CO1: CO1. Understand what Explainable AI is, its scope, and impact on various domains. CO2: Understand Global vs Local Explanations and their applications. CO3: Identify and evaluate the most used XAI techniques and algorithms. CO4: Use Python to apply Explainer algorithms/methods and interpret the results
Text Books & Reference Books
R. S. Sutton and A. G. Barto. Reinforcement Learning - An Introduction. MIT Press. Abhishek Nandy, Manisha Biswas, Reinforcement Learning: With Open

AI, TensorFlow and Keras Using Python, Publisher: Apress © 2018, ISBN 9781484232842 2. Howard M. Schwartz , Multi-Agent Machine Learning: A Reinforcement Approach, Publisher: John Wiley & Sons (US) © 2014, ISBN 9781118362082 3. Michael Hu, The Art of Reinforcement Learning: Fundamentals, Mathematics, and Implementations with Python, Publisher: Apress © 2023 ISBN 9781484296059
Reference Books
1. Mike O'Docherty, " Object-Oriented Analysis & Design: Understanding System Development with UML 2.0", John Wiley & Sons . 2. James W-Cooper, Addison- Wesley, "Java Design Patterns-A Tutorial", Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides, "Design patterns: Elements of Reusable object-oriented software", - Addison-Wesley.

Subject Code	Course Name	L – T – P	Credits
CE-606A	Software Engineering & System Modelling	3-0-0	03
Course Objectives: Major objective is to learn basic principles of Software Engineering and Design, which can facilitate the resource efficient model of the Software Systems.			
Course Contents			
Unit I Software Development Process, Planning software project, Cost, Scheduling and Risk Management. Metrics, Design Principles, Introduction to Object Oriented Design.			
Unit II Introduction to OOAD What is OOAD? What is UML? What are the Unified process(UP) phases, Case study the NextGen POS system, Inception-Use case Modeling, Relating Use cases include, extend and generalization. . Elaboration -Domain Models, Finding conceptual classes and description classes, Associations, Attributes, Domain model refinement Finding conceptual class hierarchies, relationships, UML activity diagrams and modelling			
Unit III			

System sequence diagrams (SSD) -Relationship between sequence diagrams and use cases Logical architecture and UML package diagram, Logical architecture refinement, UML class diagrams, UML interaction diagrams

Unit IV

GRASP: Designing objects with responsibilities Creator, Information expert, Low Coupling, Controller, High Cohesion, Designing for visibility, Applying GoF design patterns adapter, singleton, factory and observer patterns.

Unit V

UML state diagrams and modeling -Operation contracts, Mapping design to code, UML deployment and component diagrams.

Course Outcomes

After completing this course, the students will be able to:

CO1: CO1. Understand what Explainable AI is, its scope, and impact on various domains.

CO2: Understand Global vs Local Explanations and their applications.

CO3: Identify and evaluate the most used XAI techniques and algorithms.

CO4: Use Python to apply Explainer algorithms/methods and interpret the results

Text Books

1. Software Engineering- Pankaj Jalote, TMH Software Engineering- Ian Sommerville, Pearson Craig Larman, "Applying UML and Patterns: An Introduction to object-oriented Analysis and Design and iterative development", Third Edition, Pearson Education

Reference Books

1. Mike O'Docherty, "Object-Oriented Analysis & Design: Understanding System Development with UML 2.0", John Wiley & Sons.
2. James W-Cooper, Addison-Wesley, "Java Design Patterns-A Tutorial", Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides, "Design patterns: Elements of Reusable object-oriented software", - Addison-Wesley.

Subject Code	Course Name	L – T – P	Credits
CE 608	Simulation of Wargames	3-0-0	03
Course Objectives: • Demonstrate the ability to formulate specific study questions concerning international events and formulate hypothesis that can be tested through experimentation with computer simulation tools.			

- Develop an understanding of the capabilities and limitations of modern modeling and simulation techniques as applied to the analysis of strategic international events.
- Demonstrate an understanding of accepted methodologies and practices concerning the creation and use of computer simulations to study international events to derive reasoned and justifiable conclusions.
- Demonstrate an understanding of the underlying models, abstractions, and software realizations used in modern wargame simulations.
- Demonstrate an understanding of the basic software architecture and elements of modern wargame simulations.
- Demonstrate the ability to communicate complex concepts to multidisciplinary teams including students from computing and international affairs backgrounds.
- Demonstrate the ability to understand and incorporate concepts from a different discipline and integrate them in the development and use of wargame simulations.
- Demonstrate the ability to collect and incorporate data from historical and other records for use in wargame simulation tools.
- Students will be proficient in basic mathematical skills and be able to formulate problems in international affairs mathematically if appropriate. Use software, process and analyze information, quantitative and qualitative methods

Course Contents

Unit I

The general principles of modelling and simulation, The role of modelling and simulation in supporting Defence decision making, training and analysis, The typical components of M&S systems, The technologies of live, constructive and virtual simulation and their Defence applications, An introduction to defence synthetic environments, Organisations involved in Defence M&S, both in the UK and elsewhere, Practicals hands-on with different Defence M&S systems. Verification and Validation of Defence M&S solutions.

Unit II

Different approaches for implementing Defence M&S solutions including: Intelligent Systems techniques and issues, Discrete Event Simulation, System Dynamics modelling, basics of game theory, RL-based algorithms for playing games, AlphaGo and AlphaZero, AR/VR, Applications of real-time computer graphics, including standards. Typical composition of virtual simulator systems – including Display systems and Motion Systems, Relevant architectures and standards such as CIGI (Common Image Generator Interface),

Geospatial data and terrain/environment construction, Workflow, creation, adaptation and integration of components in virtual simulation solutions

Unit III

Virtual Reality (VR), Mixed Reality (MR), Augmented Reality (AR), Extended Reality (XR), Emerging and developing technologies. Software Development, Implementation and Management. Acquisition of Defence M&S. Introduction: An introduction to the

methods used in combat modelling and their application in support of defence decision making and training. Combat Simulation: The basic principles of discrete event Monte Carlo simulations of combat, illustrated through the use of a simple engagement model. Extension of the concepts to allow more realistic representation of the battlefield. Aggregated models of combat. Lanchester's Equations: The deterministic and stochastic Lanchester equations for direct and indirect fire as used for both homogeneous and heterogeneous forces. The application of Lanchester's equations in current models of combat.

Unit IV

War Gaming/Interactive Simulation: The underlying principles of war gaming and the interactive simulation of combat as used for the assessment, testing and training of military forces and their equipment. The synthetic battlefield. Synthetic Environments: Constructive, virtual and live simulations of combat. Manual Combat Wargames. Other gaming techniques. War Gaming and Combat Modelling Practicals: The practical application of war gaming and combat modelling with issues such as : data and scenarios, terrain modelling, combat algorithms (attrition and movement), the representation of human factors, measures of effectiveness, the verification and validation of combat models, automated forces, simulation for training and distributed simulation.

subject Code	Course Name	L – T – P	Credits
CE601A	Interpretable and Explainable AI	3-0-0	03
Course Objectives: - To introduce the fundamental principles and methodologies of interpretable and explainable AI (XAI), with a focus on the development of transparent and trustworthy machine learning models. - The course will cover key XAI techniques and algorithms, including rule-based models, feature importance analysis, model-agnostic approaches, and post-hoc explanation methods.			
Course Contents Unit I Introduction to Explainable AI (XAI): definition, need, and importance, key terminologies: interpretability vs explainability, transparency, fairness, accountability; taxonomy of XAI techniques: intrinsic vs post-hoc, model-specific vs model-agnostic, local vs global interpretability; trade-off between model accuracy and explainability; human-centered AI and user-friendly explanations. Unit II			

Intrinsically interpretable models including linear regression, logistic regression, generalized linear models (GLM), Decision Trees, and Generalized Additive Models (GAM). Unit III XAI methods including feature importance, Partial Dependence Plot (PDP), Conformal Prediction, and Individual Conditional Expectation (ICE); techniques for analyzing feature influence at a global level; comparison of global explanation methods. Unit IV Saliency maps, Class Activation Maps (CAM), Cluster Analysis of CAMs, Local Relevance Propagation (LRP), Local Interpretable Model-Agnostic Explanations (LIME), Shapley Additive Explanations (SHAP), and Integrated Gradients (IG)
Course Outcomes
After completing this course, the students will be able to: CO1: CO1. Understand what Explainable AI is, its scope, and impact on various domains. CO2: Understand Global vs Local Explanations and their applications. CO3: Identify and evaluate the most used XAI techniques and algorithms. CO4: Use Python to apply Explainer algorithms/methods and interpret the results
Text Books
1. Molnar, Christoph. Interpretable Machine Learning. Leanpub 2019 Online version publicly available at: https://christophm.github.io/interpretable-ml-book/overview.html
Reference Books
1. Denis Rothman. Hands-On Explainable AI (XAI) with Python. Data - Packt 2020

LIST OF MOOC COURSE FOR 3 CREDITS

Sr No.	Course ID	Course Name	SME Name	Institute	Duration	PG
1	noc25-cs86	Distributed Optimization and Machine Learning	Prof. Mayank Baranwal	IIT Bombay	12 Weeks	PG
2	noc25-cs98	Applied Accelerated Artificial Intelligence	Prof. Satyajit Das, Prof. Satyadhyam Chickerur, Prof. Bharatkumar Sharma, Prof. Adesuyi Tosin	IIT Guwahati KLE Technological University NVIDIA	12 Weeks	PG
3	noc25-cs108	Software Engineering	Prof. Rajib Mall	IIT Kharagpur	12 Weeks	PG
4	noc25-cs109	Software Project Management	Prof. Rajib Mall, Prof. Durga Prasad Mohapatra	IIT Kharagpur	12 Weeks	PG
5	noc25-cs111	Stochastic Approximation: Theory and Applications	Prof. Gagan Chandrashekar Mallika Thoppe	IISc Bangalore	12 Weeks	PG
6	noc25-cs115	Computational Complexity	Prof. Subrahmanyam Kalyanasundaram	IIT Hyderabad	12 Weeks	PG
7	noc25-cs116	Cyber Security and Privacy	Prof. Saji K Mathew	IIT Madras	12 Weeks	PG
8	noc25-cs128	Secure Computation: Part II	Prof. Ashish Choudhury	IIIT Bangalore	12 Weeks	PG
9	noc25-cs151	Algorithmic Game Theory	Prof. Palash Dey	IIT Kharagpur	12 Weeks	PG
10	noc25-cs158	Second Level Algorithms	Prof. Palash Dey	IIT Kharagpur	12 Weeks	PG
11	noc25-cs159	Artificial Intelligence: Concepts and Techniques	Prof. V. Susheela Devi	IISc Bangalore	12 Weeks	PG

Department of Applied Mathematics

Institute Vision

To be a centre of Excellence of international repute for Education, Training and research in Advanced Technologies with a view to strengthen national security and self-reliance.

Institute Mission

To evolve as an Innovative Unique Research University to develop indigenous contemporary Defence related technologies in Navigation Systems, Wireless Sensors, Efficient Propulsion Systems, Weapon Systems for DRDO and Defence Services, provide technological solutions to the Services to optimize combat battlefield effectiveness and above all produce qualified quality manpower which can truly become an instrument for building a strong indigenous technology base in the context of creating a performing Defence Industrial Base in India.

Department Vision

To be a Center of Excellence of International repute to provide high-quality education, research, and training in the area of Modelling & Simulation (M&S) and Data Science (DS) to promote innovation and entrepreneurship skills among the students with a view to strengthen national security and self-reliance.

Department Mission

The Department of Applied Mathematics is committed to providing quality education, research, and service that promotes the development of critical thinking, problem-solving, and innovation in the fields of computer engineering and mathematical sciences. Our mission is to:

M1:	To build strong education, teaching and research environment in the field of Modelling & Simulation (M&S) and Data Science (DS) to meet requirements from Defence, specially related to national security.
M2:	To strive for continuous learning, innovation, entrepreneurship and quality research culture amongst the student community through effective government, industry & academia collaboration.
M3:	To encourage ethics, team work and technological leadership skills among students to solve complex engineering problems collaboratively by imparting strong theoretical foundation complemented with extensive practical training.
M4:	Engage with industry, government, DRDO, Tri-services and PSUs to transfer knowledge and technology, and to contribute to the social and economic development of our region and beyond.

M. Tech in Modelling and Simulation

Introduction: M. Tech. (Modelling & Simulation) programme is being offered by the Department of Applied Mathematics. M. Tech in Modelling and Simulation programme was provisionally accredited by NBA. The Department of Applied Mathematics came into existence with the inception of the Institute of Armament Studies in 1953 as the Faculty of Applied Mathematics. The faculty constituted of three departments: (1) Applied Mathematics (2) Ballistics (3) Statistics. In 1991 the three departments merged into one and named it as Department of Applied Mathematics.

The aim of the programme is to provide training in-depth knowledge of various modelling and simulation techniques and also mathematical topics to various courses conducted at DIAT. The present faculty strength of the school is twelve. The school is also actively engaged in handling the projects from various agencies. Since then, the school members have been actively involved in the research in different fields of numerical solution to partial differential equations, numerical methods, optimization, applied mathematics such as ballistics, flight dynamics, hydro-dynamics, hydro-ballistics, computer science, image processing, statistics and probability. Recently the school has also developed expertise in the advanced Modelling and Simulation techniques like Neural Network, Fuzzy Logic and Genetic Algorithm, Parallel Computing, Cryptography and Machine Learning, Cyber Security, IoT and Computer Networks.

The programme is of two years duration where the student undergoes basic training in the subjects related to mathematical modelling & simulation through classroom teaching in the first and second year. During this period the student is also exposed to various simulation tools and practical's. The second year is the dissertation phase where the student works under the guidance of a recognized guide on a problem related to modelling and simulation. Course curriculum will be updated periodically to keep pace with contemporary technological advancement.

Research Areas

- ❖ Mathematical Modelling & Simulation
- ❖ Partial Differential Equations & their applications
- ❖ Image Processing
- ❖ Numerical Analysis of PDEs
 - Finite Elements Method
 - Boundary Element Method
 - Domain Decomposition Method & Fictitious Domain Method
- ❖ Finite Element Analysis in Fluid Flow through Porous Media
- ❖ Boundary Layer Theory
- ❖ Computational Fluid Dynamics
- ❖ Numerical Parallel Algorithms and Parallel Computing.

- ❖ Bio-Mechanics
- ❖ Cryptography
- ❖ IoT
- ❖ Computer Vision
- ❖ Computer Networks
- ❖ Cyber Security

Programme Outcomes (POs)

PO1	The school imparts higher education and training in the field of modelling and simulation meeting the defence, industries and academic requirement of the country.
PO2	Various courses offered under his programme help to develop various mathematical models cutting across the boundaries and to understand simulation techniques.
PO3	After providing the appropriate training in computation and simulation methods and imparting knowledge on contemporary issues, students are well equipped to tackle challenges in the related field.
PO4	This is a unique capability which helps the students to establish themselves as a successful professional.
PO5	An ability to function on multidisciplinary teams involving interpersonal skills.
PO6	An ability to identify, formulate and solve engineering problems of multidisciplinary nature

Eligibility Criteria for Admission to join in this programme

M. Tech Modelling & Simulation	The candidate must have a Valid GATE Score and marks / CPI (Cumulative Performance Index), referred to in subsequent section, implies a minimum of 55% marks/SPI of 5.5 (on a 10-point scale) as long as it is at least seven percent higher than the minimum pass marks/CPI from a recognized Institute / University in B. Tech / BE degree (OR) MSc / MS degree in CS / IT / Mathematics / Statistics / Physics / Electronics, Provided 1) Mathematics is one of the subject at the graduate level and 2) Valid GATE Score in CSE / IT / ECE / ME / AE / CE / EE / IN / MA / ST/DA/PH 3) For Self-Financed and Sponsored candidates GATE is exempted

CSE - Computer Science Engineering

AE - Aerospace Engineering

ME - Mechanical Engineering

EE – Electrical Engineering

MA- Mathematics

DA- Data Science and Artificial Intelligence

IT - Information Technology

ECE - Electronics & Communication Engineering

CE – Civil Engineering

IN – Instrumentation Engineering

ST- Statistics

PH - Physics

Organization of M.Tech programme:

This programme is of four-semester duration. In first and second semester have six courses along with practical component of each course. The respective course instructor will give assignments / practical problems from the course component and these will be solved in Modelling and Simulation Lab. The practice problems can be solved by using Advanced Data structures (C / C++) / MATLAB / MATHEMATICA / Simula8 / Maplesim / SPSS / R / Extend Sim. etc., and all these software are licensed version and available in the department.

In the first semester all courses are compulsory. But in the second semester 2 courses are compulsory and there is an option to choose 4 elective courses, out of which two elective courses must be chosen from the department only and rest of the two elective courses can be chosen from either department or inter department courses. In each of the course component, there will be three tests and a final semester examination of every course. Half yearly evaluation of the project takes place at the end of the third semester. After the second semester, scholarship students are encouraged do a summer internship for about one and half months at their place of choice whereas the sponsored category students are encouraged to identify their project work related to their field (labs) to have collaboration a with DIAT. The third and fourth semester will have only dissertation phase (work) – 1, and dissertation phase (work) – 2 (this is in continuation of dissertation phase (work) – 1) respectively. The department faculty will encourage and help to students to take their projects from DRDO labs / premier institutes or as per student's choice. This will be entirely based student's own arrangements and expenses. The department will not sponsor for this; except official arrangements, like issuing no-objection certificate etc. At the end of the final semester, he/she submits a thesis and makes a presentation about the project, which is evaluated by the Internal and External examiners. No credits will be counted for attending an audit course.

Semester I:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AM 601	Numerical Methods for Differential Equations	3	0	3
2.	AM 602	Mathematical Modelling & System Analysis	3	0	3
3.	AM 603	Optimization Techniques	3	0	3
4.	AM 604	Advanced Statistical Techniques	3	0	3
5.		Elective 1	3	0	3
6.	AM 609L	Data Science: Tools & Techniques (LAB)	0	6	3
7.	PGC-601	Research Methodology and IPR	2	0	2
		Total	17	6	20

Semester II:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AM 621	Soft Computing techniques	3	0	3
2.	AM 622	Simulation of Linear and Nonlinear Systems	3	0	3
3.		Elective I	3	0	3
4.		Elective II	3	0	3
5.		Elective III	3	0	3
6.	AM 620L	Machine Learning and Deep Learning (LAB)	0	6	3
7.	PGC-602	Personality Development and Communication skills	2	0	0
		Total	17	6	20

Semester III:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AM 651	Dissertation & Seminar Phase – I	40**		20
		Total	40		20

Semester IV:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AM 652	Dissertation & Seminar Phase – I	40**		20
		Total	40		20

* 1 Credit for Theory (or Tutorial) means 1 contact hour in a week and 1 credit for practical means 2 contact hours in a week.

****Contact Hours per week Note:** During non teaching days, Internship / Industrial Tour will be accepted for all students relevant to the dissertation work especially Modeling and Simulation.

List of Electives are given Below:

Sl. No.	Course Code	Course
1	AM 605	Linear Algebra and Applications
2	AM 623	Machine Learning
3	AM 624	Big Data Analytics
4	AM 625	Image and Video Analytics
5	AM 626	Computational Heat and Mass Transfer
6	AM 627	Ballistics
7	AM 628	Computational Number Theory and Cryptography
8	AM 629	Calculus of Variations and Integral Equations
9	AM 630	Domain Decomposition Methods for Partial Differential Equations
10	AM 631	Multigrid Methods
11	AM 632	Introduction to Non-Newtonian Fluids
12	AM 633	Bio-Mechanics
13	AM 635	Finite Elements: Theory and Algorithms
14	AM 636	Cloud Computing
15	AM 640	AI for Medical Image Analysis
16	AM 642	Computer Vision with Pattern Recognition
17	CE 631	Deep Learning
18	CE 632	Computer Vision
19	AM 644	Digital Twins

AM 601 : Numerical Methods for Differential Equations

Course Code	AM 601
Course Name	<i>Numerical Methods for Differential Equations</i>
L – T – P – C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Compulsory
Offered in (SPRING / AUTUMN)	AUTUMN
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
CO1: Understand the methods for solving ODE's and PDE's using various Numerical methods that can help to make decisions for practical problems in industries and apply basic concepts of mathematics to formulate problem which can be solved by an appropriate Numerical method. CO2: Students are able to understand the importance of Numerical method that could arise out of various processes and judge an appropriate method that could be used to solve the governing equations of a model. CO3: Students are able to analyse and appreciate the variety numerical methods such as FDM and FVM that can be applied to solve a specific model. CO4: Students are able to implement, develop and promote research interest in applying numerical methods in problems of Engineering and Technology.	
Solution of Ordinary Differential Equations: Taylor series method – Euler and Modified Euler methods – Runge kutta methods– Multistep methods – Milne's method – Adams Moulton method. Boundary Value Problems and Characteristic Value Problems: The shooting method – solution through a set of equations – Derivative boundary conditions – Characteristic value problems – Eigen values of a matrix by Iteration – The power method. Numerical Solution of Partial Differential Equations- Finite Difference Methods (FDMs) : (Solutions of Elliptic, Parabolic and Hyperbolic partial differential equations). Representation as a difference equation – Laplace's equation on a rectangular region – Iterative methods for Laplace equation – The Poisson equation – Derivative boundary conditions – Solving the equation for time-dependent heat flow (i) The Explicit method (ii) The Crank Nicolson method – solving the wave equation by FDMs. Alternate Direction Implicit (ADI) method, Maccormack predictor-corrector method, Lax-Wendroff Method. Dirichlet's problem, Neumann problem, mixed boundary value problem. Higher order compact (HOC) scheme. Basic concepts of finite volume method (FVM): Gauss-divergence theorem. Four basic rules. General discretization techniques. Source term linearization and boundary conditions. Over relaxation and under relaxation techniques. Location of control volume faces. Staggered grid concept. Application of FVM. Advantage and disadvantage with the FDM. Text Books: 1. Numerical Solutions of Differential Equations, 2nd Ed., 1984, M. K. Jain, Wiley Eastern. 2. Numerical Solution of Partial Differential Equations, 3rd Ed., 1986, G.D. Smith, Oxford Univ. Press. Reference Books: 1. Finite Difference Schemes and Partial Differential Equations, 2004, J. C. Strikwerda, SIAM. 2. Computational Methods for Partial Differential Equations, 2007, M. K. Jain, S. R. K. Iyengar, New Age International. 3. Applied Numerical Analysis, 7th Ed., 2003, Curtis F. Gerald, Patrick O. Wheatley, Pearson Education. 4. Numerical Methods Using MATLAB, 4th Ed., 2004, John H. Mathews, Kurtis D. Fink, Pearson Education. 5. An Introduction to Computational Fluid Dynamics - The Finite Volume Method, 2nd Ed., 2007, H. K. Versteeg, W. Malalasekera, Pearson Education.	

AM 602 : Mathematical Modelling and System Analysis

Course Code	AM 602
Course Name	<i>Mathematical Modelling and System Analysis</i>
L – T – P - C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Compulsory
Offered in (SPRING / AUTUMN)	AUTUMN
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: CO1: Students are able to understand the importance of modeling the physical phenomenon and their simulation on a digital machine over the physical experiments. Students also understand the power of numerical experiments over physical experiments with mathematical modeling techniques. CO2: Students are able to analyze the continuous and discrete models with dimensional analysis and their applications in real-life scenarios. CO3: Students are able to understand and model the time-invariant systems with the linear approximation of the nonlinear systems. CO4: Students are able to understand the basics of the simulator technology with their application in developing cutting-edge technology, in particular with the applications in the defence sector.	
Course Contents Mathematical Modelling: Introduction to modelling and simulation, Classification of systems into continuous and discrete, Structural characterization of mathematical model and validation techniques. Modelling Techniques: Dimensional analysis: Concept behind dimensional approach, Buckingham Pi theorem, Models using dimensional approach. Continuous approach: Models based on physical laws. Discrete Approach: Models based on discrete approach. Prey - Predator models. Combat Modelling: Modelling the Lanchester laws with System Dynamics. System Analysis: The state of a system, mathematical models of continuous linear lumped parameter, time invariant systems, Discrete time systems, Linear approximation of non-linear systems, Topological models of system, Block diagram representation, Signal flow graph, and Mason's rule. A generalized approach to modelling. Principles of conservation and continuity and Applications. Basics of simulator technology. Text Books 1. Modelling Mathematical Methods & Scientific Computations, 1995, Nicola Bellomo & Luigi Preziosi, CRC Press. 2. Systems Modelling and Analysis, 2003, I.J. Nagrath, M. Gopal, Tata McGraw Hill, New Delhi. 3. Introduction to Mathematical Systems Theory - A behavioural approach, 2nd Ed., 2008, Jan Willen Polderman, Jan C. Willems, Springer. Reference Books: 4. Introduction to System Dynamics, 1967, J.L. Shearer, A.T. Murphy, H.H. Richardson, Addison & Wesley. 5. Introduction to System Analysis, 1985, T.H. Glisson, McGraw Hill.	

AM – 603 : Optimization Techniques

Course Code	AM 603
Course Name	Optimization Techniques
L – T – P - C	3 – 0 - 0 – 3
Offered as (Compulsory / Elective):	Compulsory
Offered in (SPRING / AUTUMN)	AUTUMN
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: CO1: Understand the application of various optimization techniques that can help to make decisions for practical problems in industries and apply basic concepts of mathematics to formulate an optimization problem. CO2: Understand the importance of optimization of industrial process management with the theory of optimization methods and algorithms developed for solving various types of optimization problems. CO3: Analyze and appreciate the variety of performance measures for various optimization problems such as Sensitivity analysis, Risk analysis and Portfolio Management, etc. CO4: Implement, develop and promote research interest in applying optimization techniques in problems of Engineering and Technology. And the mathematical results and numerical techniques of optimization theory to concrete Engineering problems.	
Course Contents Linear programming: Simplex method, Two-phase method, Big-M method, Duality, Integer linear Programming, Dynamic Programming, Sensitivity analysis. Assignment problem: Hungarian's algorithm, Degeneracy, applications, unbalanced problems, traveling salesman problem. Classical optimization techniques: Single variable optimization with and without constraints, multi-variable optimization without constraints, multi-variable optimization with constraints – method of Penalty methods Lagrange multipliers, Kuhn-Tucker conditions. Numerical methods for optimization: Minimization and maximization of convex functions- Local & Global optimum- Convergence-Speed of convergence. One dimensional minimization - Elimination methods: Fibonacci & Golden section search - Gradient methods - Steepest descent method, Nelder Mead's Simplex search method, methods of line search; Quasi-Newton methods: DFP, BFGS. CPM/PERT: Simulation of CPM/PERT network, Analysis of an activity network, Simulation of inventory system and manufacturing system.	
Text Books	
1. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India. 2. Engineering Optimization: Theory and Practice, 4th Ed., 2009, S.S. Rao, Wiley Eastern Ltd. 3. Optimization: Theory and Practice, 2004, MC Joshi, KM Moudgalya, Narosa.	
Reference Books	
1. Mathematical Programming Techniques, 3rd Ed., 1991, N. S. Kambo, East-West Press, New Delhi. 2. An Introduction to Optimization, 2nd Ed., 2001, Chong, E. k. and Zak, S. H., Wiley India. 3. Linear and Nonlinear Programming, 3rd Ed., 2008, Luenberger, D. G. and Ye, Y., Springer. 4. Mathematical Programming Techniques, 1997, Kambo, N.S., East-West Press. 5. Introduction to Optimization, 1988, Beale, John Wiley. 6. Numerical Methods and Optimization, Hari Arora, S.K. Kataria & Sons 7. Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer 8. Nonlinear Programming Theory and Algorithms, 1979, Bazarra M.S., Sherali H.D. & Shetty C.M., John Wiley, New York.	

AM 604 : Advanced Statistical Techniques

Course Code	AM 604
Course Name	<i>Advanced Statistical Techniques</i>
L – T – P - C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Compulsory
Offered in (SPRING / AUTUMN)	AUTUMN
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: CO1: Understand the fundamental concepts of probability and statistics such as Axioms, addition law, conditional probability, Baye's principle etc., and their real-life application to predict the data. CO2: Understand the importance of Probability Distributions such as Binomial, Poisson, Normal and Exponential Distributions and their properties and problems on special probability distributions. CO3: Analyze and appreciate the statistical theory behind Curve fitting, regression modeling and Chi Square Test, student test & Fisherman test. CO4: Understand the theory behind Design and Analysis of Experiments: Need for conducting Experiments, and their possible applications.	
Course Contents Probability Theory: Sample Spaces- Events - Axioms – Counting - Conditional Probability and Bayes' Theorem – The Binomial Theorem – Random variable and distributions: Mean and Variance of a Random Variable-Binomial-Poisson-Exponential and Normal distributions. Sampling Distributions & Descriptive Statistics: The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population, Sampling distributions (Chi-Square, t, F, z). Test of Hypothesis- Testing for Attributes – Mean of Normal Population – One-tailed and two-tailed tests, F-test and Chi-Square test - - Analysis of variance ANOVA – One way and two-way classifications. Introduction to Statistical modelling, Regression modeling for Normal response and quantitative explanatory: Introduction to Statistical modeling, Variables, Simple and Multiple regressions, Model building and validation Comparison of regressions. Stochastic process: Basic idea of random processes, Stationary, Markov processes, Markov chains and applications, Introduction to ergodicity.	
Text Books	
1. Stochastic Process, 3rd Ed., 2010, J. Medhi, New Age Science Ltd. 2. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Academic Press. 3. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.	
Reference Books	
1. All of Statistics: A Concise Course in Statistical Inference, 2003, Larry Wasserman, Springer. 2. Introduction to Statistical Modelling, 2010, W. J. Krzanowski, Oxford university press. 3. Schaum's outlines Probability and statistics, 4th Ed., 2013, Murray R. Spiegel, John Schiller, R Alu Srinivasan, Tata McGraw Hill 4. Learning R, O'Reilly, 2013, Richard Cotton. 5. Introductory statistics with R, 2008, Dalgaard, Peter Springer Science & Business Media. 6. A Handbook of Statistical Analysis Using R, Second Edition LLC, 2014, Brain S. Everitt. 7. Introduction to Probability and Statistics for Engineers and Scientists", 4th Ed., 2009, Sheldon M. Ross, Academic Press. 8. R Cookbook, O'Reilly, 2011, Paul Teetor.	

AM 605 : Linear Algebra and Applications

Course Code	AM 606	
Course Name	Linear Algebra and Applications	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	AUTUMN	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: Students will build the fundamentals of linear algebra CO2: Students appreciate the applications of different matrix decomposition methods CO3: Students can correlate the related applications of linear algebra CO4: Students should be in a position to formulate the relevant real-world problems using the understanding of linear algebra		
Course Contents Unit I: Introduction to Fundamental Linear Algebra Problems and Their Importance, Linear Transformations, Linear Variety, Range Space and Rank, Null Space and Nullity, Homomorphism, Matrix of Linear Transformations, Matrix Representation of a linear transformation, Structure of the solutions of the matrix equation $Ax = b$, Change of bases. Unit II: Matrix and vector norms, floating points arithmetic, forward and backward stability of algorithms, conditioning of a problem, perturbation analysis, solving linear systems, Gaussian elimination, LU factorization, Pivoting, Cholesky decomposition, Iterative refinement, QR factorization, Gram-Schmidt orthogonalization, Projections, Householder reflectors, Given’s rotation. Unit III: Singular Value Decomposition, Rank and matrix approximations, image compression using SVD, Least squares and least norm solution of linear systems, pseudoinverse, normal equations, Eigenvalue problems, Gershgorin theorem, Similarity transform, Eigenvalue & eigenvector computations and sensitivity, Power method, Schur decomposition, QR iteration with & without shifts, Hessenberg transformation, Rayleigh quotient, Symmetric eigenvalue problem, Computing the Singular Value Decomposition, Golub-Kahan-Reinsch algorithm, Chan SVD algorithm, Krylov subspace methods: Lanczos, Arnoldi, MINRES, GMRES, Conjugate Gradient.		
Text Books		
1. Iterative Methods for Sparse Linear Systems, 2nd Ed., 2003, Y. Saad, SIAM. 2. Introduction to Linear Algebra, 6th Ed., 2023, Gilbert Strang, Wellesley-Cambridge Press.		
Reference Books		
1. Fundamentals of Matrix Computations, 2nd Ed., 2002, D. S. Watkins, John-Wiley. 2. Numerical Linear Algebra and Applications, 2nd Ed., 2010, B. N. Datta, SIAM. 3. Applied Numerical Linear Algebra, 1997, J. W. Demmel, SIAM. 4. An Introduction to numerical linear algebra, 1994, C. G. Cullen, Charles PWS Publishing. 5. Linear Algebra and its Applications, 2013, C. Lay David, Pearson. 6. Matrix Computation, 1996, G. Golub, C. F. Van Loan, John Hopkins		

AM 609 : Data Science: Tools and Techniques

Course Code	AM 609
Course Name	Data Science: Tools and Techniques
L – T – P - C	3 – 0 - 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	AUTUMN
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: CO1: Understand the fundamental concepts of data science and terminology. CO2: Understand the fundamental concepts of data science process and machine learning concepts. CO3: Understand the fundamental concepts of tools used in data science.	

CO4: Fundamental concepts of large data & Data Visualization. CO5: To implement the aspects of Data Science through case studies.
Programming Language: Introduction to Python, Programming Interfaces, Spyder, Python script file, Print Message to Standard Output, variables and data types, Reading Input from console, Type Conversion, Arithmetic Operators and Conditions Control Flow - Relational Operators, if...else statement, if...else if...else statement, Logical operators, While Loops, break and continue statement, Loops with else statement, pass statement, Python for loop, Range Function, Lists: Creating List, Accessing elements from List, Inserting and Deleting Elements from List, List Slicing, Joining two list, Repeating sequence, Nested List, Built-in List Methods and Functions, Searching elements in List, Sorting elements of List Python Data Structures: Python Set, Creating Set, Adding/Removing elements to/from set, Python Set Operations: Union, Intersection, Difference and Symmetric Difference, Python Tuple, Creating Tuple, Understanding Difference between Tuple and List, Accessing Elements in Tuple, Python Dictionary, Creating Dictionary, Accessing / Changing / Deleting Elements in Dictionary Data Pre-processing Numpy, Dask, Xarray: Numpy, Creating Numpy array, Numpy data type, Accessing Elements in Numpy, Element wise calculations, Vectorized Operation, Numpy Subsetting, Built-in Methods of Numpy, Array creation Methods: arange, linspace, eye, Numpy 2D Array, 2D Array Indexing, Matrix Calculations , Dask, Parallel computing with Dask, Xarray integration with Dask Pandas: Reading Files, Writing Files, Loading Data with Pandas, Selecting Specific Columns, Selecting rows using labels: loc, Selecting rows using position: iloc, Adding and Removing rows and Columns, Filtering Data Frames, Importing Data from csv Files, Missing Data Handling, OnHot Encoder, Label Encoding, Data Splitting, Training Data, Importance of Test Data. Built-in Dictionary Methods and Functions: Data Analytics, Data preprocessing, Analyzing data, Handling missing data, Applying Machine learning techniques to analyze data Functions: Defining Functions in Python, Function Argument, Single Parameter Functions, Function Returning single Values, Functions with multiple parameters, Function that return Multiple Values, Functions with Default arguments, Named arguments, Scope and Lifetime of Variables, Global specifier Data Visualization with Matplotlib, Seaborn: Introduction to Matplotlib, Basic Plotting with Matplotlib, Line Plot on Example DataSet, Exploring the plot Options, Other types of Plots, Bar Plot, Pie Plot, Histograms Regression for data analysis: Introduction to regression and Classification, Types of Classification, Simple Linear regression Intuition, Sci kit Learn Library, Hands on Lab on Simple Linear Regression, Performance Evaluation Regression and Classification Part 2: Multivariable Linear regression, Handson Example on Multivariable LR, Performance Evaluation, Improving the Performance, Backward Elimination method, Other types of Regression Models, Performance Evaluation of different Regression Models Classification in Machine Learning : Classification Introduction, K-Nearest Neighbours, Decision Tress, Naïve Bayes algorithm, Introduction to Neural Networks
Text Books
1. Mastering Python for Data Science, 2015, Samir Madhavan, Packt Publishing. 2. Python Machine Learning, 2015, Sebastian Raschka Packt Publishing. 3. Python Basics: A Self-Teaching Introduction, 2018, H. Bhasin, Mercury Learning and Information. 4. Beginning Python, 2008, Magnus Lie Hetland, Apress Berkeley, CA.
Reference Books
1 Michael Roberts Beginning Python, 2005, Peter Norton, Alex Samuel, David Aitel, Eric Foster-Johnson, Leonard Richardson, Jason Diamond, Aleatha Parker, Wiley Publishing. 1. Expert Python Programming: Best practices for designing, coding, and distributing your Python software Tarek Ziadé, 2008, Packt Publishing. 2. Programming Python, 2010, Mark Lutz, O'Reilly Media. 3. Programming in Python 3: A Complete Introduction to the Python Language, 2010, Mark Summerfield, Addison-Wesley. 4. Practical programming: An introduction to computer science using Python, 2009, Jennifer Campbell, Paul Gries, Jason Montojo, Greg Wilson, Pragmatic Bookshelf. 5. Core Python Programming, 2nd Ed., 2006, Wesley Chun, Prentice Hall. 6. Core Python Applications Programming, 2012, Wesley J Chun, Prentice Hall. 7. Programming Computer Vision with Python: Tools and algorithms for analyzing images, 2012, Jan Erik Solem, O'Reilly Media.

PGC-601 : Research Methodology and IPR

Course Code	PGC-601	
Course Name	Research Methodology and IPR	
L – T – P - C	2 – 0- 0 – 2	
Offered as (Compulsory / Elective):	Compulsory	
Offered in (SPRING / AUTUMN)	AUTUMN	
Offered by (Name of Department/ Centre)	PGC/All Departments DIAT	
Course Outcomes: After completing this course, the students will be able to: CO1: Understanding the fundamentals of research and its methodology CO2: Choose the appropriate research design and develop appropriate research hypothesis for a research project CO3: Knowledge of manuscript preparation, patents and Intellectual property CO4: Technology transfer and application of IPR in various domains.		
Course Contents Unit I : Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations Unit II : Effective literature studies approaches, analysis Plagiarism, Research ethics, Unit III : Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee Unit IV : Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. Unit V : Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications Unit VI : New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.		
Texts / References		
1. Research methodology: an introduction for science & engineering students, Stuart Melville and Wayne Goddard. 2. Research Methodology: An Introduction, Wayne Goddard and Stuart Melville. 3. Research Methodology: A Step-by-Step Guide for beginners, 2 nd Ed., Ranjit Kumar. 4. Resisting Intellectual Property, 2007, Halbert, Taylor & Francis Ltd. 5. Industrial Design, 1992, Mayall, McGraw Hill. 6. Product Design, 1974, Niebel, McGraw Hill. 7. Introduction to Design, 1962, Asimov, Prentice Hall. 8. Intellectual Property in New Technological Age, 2016, Robert P. Merges, Peter S. Menell, Mark A. Lemley. 9. Intellectual Property Rights Under WTO, 2008, T. Ramappa, S. Chand.		

AM 621 : Soft Computing Techniques

Course Code	AM 621
Course Name	<i>Soft Computing Techniques</i>
L – T – P – C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Compulsory
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics

Course Outcomes: After completing this course, the students will be able to: CO1: Understand basic concepts of Fuzzy sets, neural networks, chaos, fractals and their applicability in various fields of science and technology that can help to make decisions for practical problems in industries. CO2: Students are be able to understand the importance of fuzzy sets and fuzziness that could arise out of various processes and judge an appropriate method that could be used to solve the governing model as fuzziness is inherent in large no. of models. CO3: Students are be able to analyze and appreciate the mathematics behind the variety neural networks such as perceptron learning, back propagation methods etc., that can be applied to solve a specific model. CO4: Students are be able to understand the theory behind chaos mathematically using a specific water wheel model. Also, to understand the theory behind fractals and their possible applications
Fuzzy logic: Basic concepts of fuzzy set, Operation on fuzzy sets, Fuzzy numbers Fuzzy relation, Fuzzification and Defuzzification, Fuzzy logic as generalization of two valued logic, Fuzzy system, Development of Membership functions, fuzzy classification and pattern recognition. Dynamics of Chaos: Introduction to one dimensional dynamical system, Fixed points and stability, population growth, with fixed points and stability analysis, Bifurcations (saddle -node, transcritical and pitchfork bifurcations), Introduction to chaos, Lorenz system, Lorenz attractor, Dimension of chaotic attractor, applications in communications. Fractals: Introduction to fractals, Similarity dimension of objects with techniques, Types of fractal dimensions, Generation of fractals by mathematical approach, Julia and Mandelbrot sets. Text Books 1. Fuzzy Logic with Engineering Applications, 2009, Timothy J Ross, Wiley. 2. Neural Computing: An Introduction, 2010, R. Beale, T. Jackson, Adam Hilger, CRC Press. References Books 1. Neural fuzzy systems: A Neurofuzzy Synergism to Intelligent Systems, 1996, Chin- Teng Lin and C.S.G. Lee, Prentice Hall International, INC. 2. Encounter With Chaos, 1992, Denny Gulick, McGraw Hill Inc.

AM 622 : Simulation of Linear and Nonlinear Systems

Course Code	AM 622
Course Name	<i>Simulation of Linear and Nonlinear Systems</i>
L – T – P - C	3 – 0 - 0 – 3
Offered as (Compulsory / Elective):	Compulsory
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: CO1: Students can understand the basics concepts of real systems, mathematical model, types of models, simulation and their applications. CO2: Students are be able to understand the importance of Generation of random numbers, Pseudo random numbers, generation of random variates using discrete and continuous probability distributions such as uniform, triangular. CO3: Students are be able to analyze and appreciate the uniformity and independence properties using testing of hypothesis and Chi-square, auto correlation tests. CO4: Students are be able to understand the simulation theory related to Queuing, Inventory and CPM/PERT and implement industrial and real-world problems.	

Simulation of single server and multiple server queuing system. Design (component & organisation) of a simulation experiment. Rational selection of input distribution. Output data analysis. Variance reduction techniques, Model validation. Discrete event systems, Time advance mechanism, Simulation, Monte Carlo & Stochastic Simulation. Generation of random numbers, Pseudo random numbers, Test for random number simulation of probability distribution. Discrete event simulation: simulation of single server and multiple server queuing system.

Concept of systems, Classification of systems, General Properties of Linear and nonlinear systems.

Periodic orbits, Poincare Bendixson criterion, limit cycle, bifurcation, Lyapunov Stability, basic stability and instability theorems, uniform stability, asymptotic stability, exponential stability

Text Books

1. An Introduction to Mathematical Control Theory, 1990, S. Barnett and R. G. Cameron, Oxford University Press.
2. Nonlinear Systems, 3rd Ed., 2003, H.K. Khalil, Prentice Hall.
3. Applied Nonlinear Control, 1991, J.J.E. Slotine, W. Li, Prentice Hall
4. Simulation Modeling & Analysis, 2008, Law A.M., Tata McGraw Hill.

Reference Books

1. System Modelling and Computer Simulation, 1996, Kheir N.A, Marcell Dekker.
2. Discrete-Event System Simulation, 5th Ed., 2009, Jerry Banks, John Carson, Barry L. Nelson, David Nicol, Prentice Hall
3. Operations Research: An Introduction, 2002, Taha H.A, Prentice Hall.

AM 623 : Machine Learning

Course Code	AM 623
Course Name	Machine Learning
L – T – P – C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics

Course Outcomes: After completing this course, the students will be able to: 1. Explain the core concepts of machine learning, types of learning paradigms, and issues in designing learning systems. 2. Apply supervised learning algorithms such as linear regression, decision trees, SVMs, and neural networks for prediction and classification tasks. 3. Implement unsupervised learning techniques like k-means, GMM, EM, and hierarchical clustering to discover hidden patterns in data. 4. Analyze the bias-variance tradeoff, evaluate model complexity using VC dimension, and select appropriate models using performance metrics and cross-validation techniques. 5. Demonstrate the ability to implement and evaluate machine learning models using Python for real-world datasets	
Course Contents UNIT I - Well-posed learning problems, Designing a learning system, Perspectives and issues in machine learning. Types of Machine Learning-Supervised, Unsupervised, Reinforcement learning. UNIT II- Supervised Learning Algorithms- Regression and Classification-Linear, Polynomial- Regularization, Regression based on Normal Equations, Instance-based learning-Decision Trees, Artificial Neural Networks Support Vector Machines, Support Vector Regression UNIT III- Unsupervised learning- k-means, Gaussian Mixture Models, Expectation Maximization, Hierarchical clustering, Spectral clustering. UNIT IV: Bias variance trade-off, VC dimension, Model selection, AUC-ROC, Metrics-Regression, Classification, Clustering, K Fold cross-validation. UNIT V: Python Implementation of Regression, Classification, and Clustering Algorithms.	
Text Books 1. Machine Learning, Indian Ed., 2017, Tom M. Mitchell, Tata McGraw Hill Education. 2. Machine Learning: An Algorithmic Perspective, 2nd Ed., 2014, Stephen Marsland, Taylor & Francis (CRC). 3. Machine Learning, A probabilistic perspective, 2012, Kevin Murphy, MIT Press. 4. Hands on Machine Learning with Scikit-Learn, Keras & TensorFlow, O'Reilly- 3rd Edition, 2022	
Reference Books 1. Pattern Recognition and Machine Learning, 2006, Christopher M. Bishop, Springer. 2. Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press.	

AM 624 : Big Data Analytics

Course Code	AM 624		
Course Name	Big Data Analytics		
L – T – P - C	3 – 0 – 0 – 3		
Offered as (Compulsory / Elective):	Elective		
Offered in (SPRING / AUTUMN)	SPRING		

Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: CO1: understand the building blocks of Big Data CO2: articulate the programming aspects of cloud computing (map Reduce etc) CO3: understand the specialized aspects of big data with the help of different big data application CO3: represent the analytical aspects of Big Data CO5: know the recent research trends related to Hadoop File System, MapReduce and Google File System etc	
Course Contents Unit I : Introduction to Big Data: Types of Digital Data-Characteristics of Data – Evolution of Big Data – Definition of Big Data – Challenges with Big Data – 3Vs of Big Data – Non Definitional traits of Big Data – Business Intelligence vs. Big Data – Data warehouse and Hadoop environment – Coexistence. Big Data Analytics: Classification of analytics – Data Science – Terminologies in Big Data – CAP Theorem – BASE Concept. NoSQL: Types of Databases – Advantages – NewSQL – SQL vs. NOSQL vs NewSQL. Introduction to Hadoop: Features – Advantages – Versions – Overview of Hadoop Eco systems – Hadoop distributions – Hadoop vs. SQL – RDBMS vs. Hadoop – Hadoop Components – Architecture – HDFS – Map Reduce: Mapper – Reducer – Combiner – Partitioner – Searching – Sorting – Compression. Hadoop 2 (YARN): Architecture – Interacting with Hadoop Eco systems. Unit II: No SQL databases: Mongo DB: Introduction – Features – Data types – Mongo DB Query language – CRUD operations – Arrays – Functions: Count – Sort – Limit – Skip – Aggregate – Map Reduce. Cursors – Indexes – Mongo Import – Mongo Export. Cassandra: Introduction – Features – Data types – CQLSH – Key spaces – CRUD operations – Collections – Counter – TTL – Alter commands – Import and Export – Querying System tables. Unit III: Hadoop Eco systems: Hive – Architecture – data type – File format – HQL – SerDe – User defined functions – Pig: Features – Anatomy – Pig on Hadoop – Pig Philosophy – Pig Latin overview – Data types – Running pig – Execution modes of Pig – HDFS commands – Relational operators – Eval Functions – Complex data type – Piggy Bank – User defined Functions – Parameter substitution – Diagnostic operator. Jasper Report: Introduction – Connecting to Mongo DB – Connecting to Cassandra – Introduction to Machine learning: Linear Regression – Clustering – Collaborative filtering – Association rule mining – Decision tree. Unit IV: Algorithms for massive data sets, Algorithms for SISD, SIMD environments, Linked Big Data Analysis – Graph Computing and Network Science, Big Data Visualization, Big Data Mobile Applications Unit V: Applications for massive data sets: finding similar items, mining data streams, page rank algorithm, link analysis, mining social-network graphs, semantic analysis, study of applications of big spatial-temporal data, social media data, scientific data and others.	
Text Books 1. Big Data Fundamentals: Concepts, Drivers & Techniques, 2016, Thomas Erl, Wajid Khattak, Paul Buhler, Prentice Hall, Service Tech Press. 2. Big Data and Analytics, 2015, Seema Acharya, Subhashini Chellappan, Wiley Publication. 3. Data Mining, 2012, 3rd Ed., Jiawei Han, Micheline Kamber, Micheline Kamber, Jian Pei, Elsevier.	
Reference Books 1. Introduction To Algorithms, 2009, 3rd Ed., Thomas H. Cormen, Charles E. Leiserson, Ronaldo L. Rivest, Clifford Stien, The MIT Press. 2. Big Data for Dummies, 2013, Judith Hurwitz, Alan Nugent, Fern Halper, Marcia Kaufman, John Wiley & Sons, Inc. 3. Hadoop: The Definitive Guide, 2011, Tom White, O'Reilly Publications. 4. Mongo DB in Action, 2012, Kyle Banker, Manning Publications Company. 5. Mining of Massive Datasets, 2012, Jure Leskovec, Anand Rajaraman, Jeffrey David Ulman, Cambridge University Press. 6. Big Data Analytics, 2015, Seema Acharya, Subhasini Chellappan, Wiley. 7. Big Data Fundamentals: Concepts, Drivers & Techniques, 2016, Thomas Erl, Wajid Khattak, Paul Buhler, Prentice Hall, Service Tech Press. 8. HADOOP: The definitive Guide, 2012, Tom White, O'Reilly. 9. Data Mining, 2nd Ed., 2006, Jiawei Han, Micheline Kamber, Elsevier.	

AM 625 : Image and Video Analytics

Course Code	AM 625		
Course Name	Image and Video Analytics		
L – T – P - C	3 – 0 - 0 – 3		
Offered as (Compulsory / Elective):	Elective		
Offered in (SPRING / AUTUMN)	SPRING		
Offered by (Name of Department/ Centre)	Department of Applied Mathematics		
Course Outcomes: After completing this course, the students will be able to:			
CO1: understand basic image model, and will learn basic image processing techniques to analyze the image in terms of histogram, contrast, sharpness, etc.			
CO2: learn different image enhancement techniques, and also understand the factors which degrades the quality of an image, and also learns the image restoration techniques. Different spatial filtering operations for image enhancement will be learnt along with the morphological operations.			
CO3: learn image segmentation algorithms, understands the need for image compression and learn the spatial and frequency domain techniques used for image compression.			
CO4: learn different feature extraction techniques employed for image analysis and recognition, and gets an overview on applications of image processing in Machine vision			
Course Contents			
Digital Image Fundamentals: Introduction – Origin –Steps in Digital Image Processing – Components; Elements of Visual Perception – Light and Electromagnetic Spectrum – Image Sensing and Acquisition – Image Sampling and Quantization – Relationships between pixels.			
Image Enhancement: Spatial Domain: Gray level transformations – Histogram processing – Basics of Spatial Filtering–Smoothing and Sharpening Spatial Filtering – Frequency Domain: Introduction to Fourier Transform – Smoothing and Sharpening frequency domain filters – Ideal, Butterworth and Gaussian filters.			
Image Restoration: Noise models – Mean filters – Order Statistics – Adaptive filters – Band reject – Band pass – Notch – Optimum notch filtering – Inverse Filtering – Constrained Least Square Filtering – Wiener filtering.			
Morphological image processing: Dilation, Erosion, Opening, Closing, Applications to; Boundary extraction, Region filling, Extraction of connected components.			
Image Compression: Fundamentals – Image Compression models – Error Free Compression – Variable Length Coding –Bit – Plane Coding – Lossless Predictive Coding – Lossy Compression – Lossy Predictive Coding –Wavelet Coding – Compression Standards – JPEG2000.			
Image Segmentation and Representation: Segmentation – Detection of Discontinuities – Edge Linking and Boundary detection – Region based segmentation; Representation – Boundary descriptors – Simple Descriptors – Shape numbers –Regional descriptors – Simple and Topological Descriptors – Introduction to Image Processing Toolbox – Practice of Image Processing Toolbox – Case studies–Various Image Processing Techniques.			
Object recognition: Decision-theoretic methods, SVM, feature selection methods, feature extraction methods, Maximum Output Information (MOI) for joint selection and classifier training.			
Colour models and Transformations – Image and Video segmentation - Image and video demonising- Image and Video enhancement- Image and Video compression. Object detection and recognition in image and video - Texture models Image and Video classification models- Object tracking in Video			
Text Books			
1. Digital Image Processing, 3rd Ed., 2007, R. C. Gonzalez, Richard E. Woods, Prentice Hall. 2. Digital Image Processing Using MATLAB, 2nd Ed., 2009, R. C. Gonzalez, Richard E. Woods, Steven L. Eddins, Gatesmark Publishing.			
Reference Books			
1. Digital Picture Processing, 2nd Ed., 1982, A. Rosenfeld, A. C. Kak, Academic Press. 2. Fundamentals of Digital Image Processing, 1st Ed., 1989, A.K. Jain, Prentice Hall of India. 3. Pattern Classification and Scene Analysis, 1973, R. O. Duda, P. E. Hart, John Wiley. 4. Pattern Recognition, Applications to Large Data-Set Problems, 1984, Sing-Tze Bow, Marcel Dekker. 5. Computer Vision: Algorithms and Applications, 2011, Rick Szelisk, Springer. 6. Intelligent Video Surveillance Systems, 2013, Jean-Yves Dufour, Wiley. 7. Video Analytics for Business Intelligence, 2012, Caifeng Shan, Fatih Porikli, Tao Xiang, Shaogang Gong, Springer.			

AM 626 : Computational Heat and Mass Transfer

Course Code	AM 626
Course Name	<i>Computational Heat and Mass Transfer</i>
L – T – P – C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: CO1: The students have would get an intuitive idea about the practical applications of convective fluid flow into various industrial field. CO2: After completion of this course, students can have explicit knowledge about mixed convection phenomena CO3: The computation of convective heat and mass transfer analysis would be easy for students CO4: The numerical analysis associated with the flow characteristics could be helpful in the other branches of CFD	
Philosophy of Computational Fluid Dynamics: Introduction to CFD, CFD- a research tool, CFD- a design tool, Applications and Advantages of CFD, The basic governing fluid flow equations in differential form, Models of Fluid flow, Concept of Substantial derivative, Navier-Stoke's model and Euler's model equations. Convective Heat Transfer: Introduction to convection, review of conservation equations - Forced convection in laminar flow - Exact and approximate solutions of Boundary layer energy equation for plane isothermal plate in longitudinal flow - problems. Forced convection heat transfer in laminar tube flow - forced convection in turbulent flow – Internal Flows-Correlations-Problems. Approximate analysis of laminar free convective heat transfer on a vertical plate-external flows-correlations-problems. Convective Mass Transfer Definitions of concentration and velocities relevant to mass transfer, Fick's law, species conservation equation in different forms. Steady state diffusion in dilute solutions in stationary media, transient diffusion in dilute solutions in stationary media, one dimensional non dilute diffusion in gases with one component stationary. Convective mass transfer - governing equations-forced diffusion from flat plate-Dimension less correlation's for mass transfer. Simultaneous heat and mass transfer - analogy between heat, mass and momentum transfer Finite Element Method Technique: Formulation Techniques: Methodology, Engineering problems and governing differential equations, finite elements, Variational methods-potential energy method, Raleigh Ritz method, strong and weak forms, Galerkin and weighted residual methods, Piecewise Defined Shape functions, Essential and natural boundary conditions. One-dimensional finite element methods: Bar elements. Element matrices, assembling of global stiffness matrix, Application of boundary conditions, Quadratic Element, Implementation of the FEM - The Solution Procedure. Finite Element Method Techniques in Heat & Mass Transfer problems: One-dimensional, conduction and convection problems examples. Two dimensional problems: CST, LST, four noded and eight noded rectangular elements, Lagrange basis for triangles and rectangles, serendipity interpolation functions. Axisymmetric Problems: Axisymmetric formulations, Element matrices, boundary conditions. Examples: - two-dimensional fin. Isoperimetric formulation: Concepts, sub parametric, super parametric elements, numerical integration.	
Text Books: 1. Computational Fluid Dynamics-Basics with applications, 1st Ed., 1995, John D. Anderson: McGraw-Hill Science. 2. An Introduction to Fluid Dynamics, 2010, G. K. Batchelor, Cambridge University Press. 3. Computational Fluid Mechanics and Heat Transfer, 3rd Ed., 2011, Richard H. Pletcher, John C. Tannehill, Dale Anderson, Taylor & Francis.	
Reference Books: 1. Computational Fluid Dynamics: A Practical Approach, 1st Ed., 2008, Jiyuan Tu, Guan Heng Yeoh, Chaoqun Liu, Butterworth-Heinemann. 2. Computational Methods for Fluid Dynamics, 3rd Ed., 2013, J. H. Ferziger, M. Peric, Springer. 3. Convection in Porous Media, 4th Ed., 2013, Donald A. Nield, Adrian Bejan, Springer. 4. Convective Heat and Mass Transfer, 1st Ed., 2011, S. Mostafa Ghiaasiaan, Cambridge University Press.	

5. Fundamentals of Heat & Mass Transfer, Thirumaleshwar, Pearson
6. Conduction Heat transfer, 1994, Poulikakos, Prentice Hall.
7. Analytical methods in Conduction Heat Transfer, 1971, G. E. Mayers, McGraw Hill.
8. Convective Heat and Mass Transfer, 3rd Ed., 1993, W. M. Kays, M. E. Crawford, McGraw Hill.
9. Introduction to Convective Mass Transfer, 1963, D. B. Spalding, McGraw Hill.

AM 627 : Ballistics

Course Code	AM 627
Course Name	Ballistics
L – T – P - C	3 – 0 - 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
CO1: Have a knowledge and understanding of Newtonian mechanics relating to the flight of projectiles. Energy considerations in ballistics. Weapon mechanisms. Ammunition. Overview of the main stages of ballistics (Internal, Intermediate, External and Terminal). CO2: The application of mechanics to different scenarios of ballistics. CO3: The application of law to ballistics. CO4: Develop practical skills in ballistics further, for higher level ballistics modules.	
Explosives: Explosive compounds and explosive mixtures-classification of explosives: Measurement of various explosive parameters Internal Ballistics: General introduction –Propellants-Driving Band engraving process, and the resistance to the in-bore motion of a projectile- Heating of gun barrel- Heat conduction in thick walled barrels- Numerical solution for heat conduction- Wear in gun barrels- Prediction of pressure history and muzzle velocity- The internal ballistics of leaking gun. External Ballistics: Projectile Aerodynamics: General introduction-yaw-The aerodynamic forces and moments acting on a projectile-linearised aerodynamics-centre of pressure and stability-Aerodynamic coefficients-Drag laws-Angular motion of projectiles-Gyroscopic stability-Yawing behaviour-The linearised theory of yawing motion-projectiles with slight configurational asymmetries-projectiles not obeying classical linear theory. Projectile Transitional Motion: Motion in vacuum-Motion of point mass-Trajectory modelling-constant corrections to the plane-particle trajectory, biases-variable corrections to the plane-particle trajectory, dispersion-the effect of wind. Terminal Ballistics: Kinetic Energy projectiles: Penetration into resisting medium-Empirical formulae for the prediction of penetration-Analytical models of failure modes-Numerical methods-plate charges. Design and Defeat of Armour: Introduction –Mechanical property requirements-Armour material Characteristics – Armour structure-stress-strain relationship-Waves in rods-Defeat of armour-Failure Wound Ballistics: Threshold velocity for penetration of skin, flesh, bones- Nature of wounds on entry, exit-Explosive wounds- Evaluation of injuries caused due to shot gun, rifle, hand guns and country made firearms- Method of measurement of wound ballistic parameters- post mortem and ante- mortem firearm injuries.	
Text Books: 1. The Books of Ballistics and Gunnery, 1987, War Office, UK. 2. Modern Exterior Ballistics, 1999, Robert McCoy-Schiffer publishing Ltd. 3. Interior Ballistics, 1951, HMSO publication 4. Terminal Ballistics- A Text Book and atlas of gunshot wounds, 2005, Malcom J Dodd, CRC press, Taylor & Francis publications Reference Books: 1. Firearms in criminal investigation and trials, 2017, 3rd Ed., B R Sharma, Universal Law publishing Co. Pvt Ltd. 2. Gunshot wounds- practical aspects of Firearms. Ballistics and Forensic Techniques, 3rd Ed., 2016, Vincent J. M. DiMaio, CRC press. 3. Wound Ballistics and the Scientific Background, 1995, Karl G Sellier, Beat P Kneubuehl Elsevier Science publishing Co. Inc.	

AM 628 : Computational Number Theory and Cryptography

Course Code	AM 628	
Course Name	Computational Number Theory and Cryptography	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: learn computational methods in Algebra and Number Theory. CO2: understand fundamental number-theoretic algorithms such as the Euclidean algorithm, the Chinese Remainder algorithm, binary powering, and algorithms for integer arithmetic. CO3: understand the number-theoretic foundations of modern cryptography and the principles behind their security. CO4: Understand the mathematical foundations for security of modern cryptography, asymmetric crypto-systems based on hard computational problems from Algebra and Number Theory. CO5: apply fundamental algorithms for symmetric key and public-key cryptography.		
Course Contents Introduction: Introduction to Cryptosystems, Classical Ciphers, Cryptanalysis of Classical ciphers, LFSR based stream ciphers. Shannon’s Theory, Diffie-Helman Key Exchange, Rabin Cryptosystem, Knapsack Ciphers, Digital Signature, Secret Sharing, ElGamal Cryptosystem Number Theory: Divisibility: Representations of Integers, Computer Operations with Integers, Complexity of Integer Operations, Divisibility, Prime Numbers, The Fundamental Theorem of Arithmetic, Sieve of Eratosthenes, The Distribution of Primes, Greatest Common Divisor, Euclidean Algorithm, Mersenne Numbers, Fermat Numbers, Perfect numbers Congruence: Congruences, Congruence Applications, Linear Congruences, The Chinese Remainder Theorem, Theorems of Fermat and Euler- Fermat, Wilson’s Theorem, Pseudo Primes, Carmichael Numbers, The Euler Phi-Function, The Sum and Number of Divisors, Quadratic Residue, Quadratic Reciprocity. Legendre and Jacobi Symbols, Computing Legendre symbols, Primitive Roots, Quadratic Reciprocity Law, Inter Factorization and Primality Testing Algorithms: Complexity of Number Theoretic Algorithms, Fermat’s Factorization, Kraitchik’s Improvement, Trial division, Pollard Rho Algorithm, p-1 method, CFRAC method, quadratic sieve method, elliptic curve method. Primality testing algorithms: Fermat test, Miller-Rabin test, Solovay-Strassen test, AKS test. Computing discrete logarithms over finite fields: Baby-step-giant-step method, Pollard rho method, Pohlig-Hellman method, index calculus methods, linear sieve method, Coppersmith's algorithm. Representation of finite fields: Groups, Fields, Finite Fields, Arithmetic in Finite Field, Finding Multiplicative Inverses in finite fields, Prime and extension fields, representation of extension fields, polynomial basis, primitive elements, normal basis, optimal normal basis, irreducible polynomials. Binary Fields and their application in Cryptosystems. Elliptic Curve Cryptography: Introduction to Elliptic Curves, the elliptic curve group, elliptic curves over finite fields, Schoof's point counting algorithm, Discrete Log problem for Elliptic curves, Factorization using Elliptic Curve, Advantage of Elliptic Curve Cryptography over other Public Key Cryptosystems.		
Text Books 1. Introduction to Modern Cryptography, 2nd Ed., 2008, J. Katz, Y. Lindell, Chapman & Hall/CRC. 2. Computational number theory, 2018, Abhijit Das, Chapman and Hall/CRC. 3. A Course in Number Theory and Cryptography, 2006, N. Koblitz, Springer. 4. An Introduction to theory of numbers, 2006, I. Niven, H.S. Zuckerman, H.L. Montgomery, John Wiley & Sons, Inc.		
Referenece Books 1. Elliptic curves: number theory and cryptography, 2003, L. C. Washington, Chapman & Hall/CRC. 2. Rational Points on Elliptic Curves, 2005, J. Silverman, J. Tate, Springer-Verlag. 3. Guide to elliptic curve cryptography, 2004, D. Hankerson, A. Menezes, S. Vanstone, Springer-Verlag. 4. An Introduction to Mathematical Cryptography, 2008, J. Pipher, J. Hoffstein, J. H. Silverman, Springer-Verlag. 5. Elementary Number Theory, 1998, G. A. Jones, J. M. Jones, Springer-Verlag. 6. An Introduction to Cryptography, 2001, R. A. Mollin, Chapman & Hall. 7. Number Theory for Computing, 2 nd Ed., 2002, Song Y. Yan, Springer-Verlag. 8. Introduction to Algorithms, Second Edition, 1994, T. H. Cormen, C. E. Leiserson, R. L. Rivest, Prentice Hall of India. 9. Elementary Theory of Numbers, 5 th Ed., 2004, K. Rosen, Addison Wesley.		

AM 629 : Calculus of Variations and Integral Equations

Course Code	AM 629
Course Name	<i>Calculus of Variations and Integral Equations</i>
L – T – P – C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: CO1: Students will learn the core concepts of multi variable calculus and integral equations with voltera and freedholm alternatives. CO2: Students will learn the applications of these techniques in several engineering problems. CO3: Students will learn the Greens functions, and Galerkin and Ritz approach of variational equations. CO4: Students will also learn the minimum surface of revolution and fundamental results of calculus of variations	
Course Contents Linear integral equations, some basic identities, Initial value problems reduced to Volterra integral equations, Methods of successive substitution and successive approximation to solve Volterra integral equations of second kind, Iterated kernels and Neumann series for Volterra equations. Resolvent kernel as a series in, Laplace transforms method for a difference kernel, Solution of a Volterra integral equation of the first kind. Boundary value problems reduced to Fredholm integral equations, Methods of successive approximation and successive substitution to solve Fredholm equations of second kind, Iterated kernels and Neumann series for Fredholm equations. Resolvent kernel as a sum of series. Fredholm Resolvent kernel as a ratio of two series. Fredholm equations with separable kernels, Approximation of a kernel by a separable kernel, Fredholm Alternative, non-homogenous Fredholm equations with degenerate kernels. Green's function, use of method of variation of parameters to construct the Green's function for a non-homogeneous linear second order boundary value problem, Basic four properties of the Green's function, Orthogonal series representation of Green's function, Alternate procedure for construction of the Green's function by using its basic four properties. Reduction of a boundary value problem to a Fredholm integral equation with kernel as Green's function. Hilbert-Schmidt theory for symmetric kernels. Motivating problems of calculus of variations, shortest distance, Minimum surface of revolution, Branchistochrone problem, Isoperimetric problem, Geodesic. Fundamental lemma of calculus of variations, Euler's equation for one dependant function and its generalization to 'n' dependant functions and to higher order derivatives, Conditional extremum under geometric constraints and under integral constraints. Text Books: 1. Introduction to Integral Equations with Applications, 1999, A. J. Jerri, Wiley-Interscience. 2. Linear Integral Equations: Theory and Techniques, 2013, R. P. Kanwal, New York: Academic Press. 3. Calculus of Variations, 1963, J. M. Gelfand, S. V. Fomin. Inc., Englewood Cliffs: Prentice-Hall. Reference Books: 1. Calculus of Variations with Applications to Physics and Engineering, 1974, R. Weinstock, McGraw-Hall. 2. A First Course in Integral Equations, 2 nd Ed., 2015, Abdul-Majid Wazwaz World Scientific Pub. 3. Integral equations: a practical treatment, from spectral theory to applications, 1990, P. David, S. G. David Stirling, Cambridge University Press.	

AM 630 : Domain Decomposition Methods for Partial Differential Equations

Course Code	AM 630
Course Name	Domain Decomposition Methods for Partial Differential Equations
L – T – P – C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: CO1: Students will learn the core concepts of domain decomposition methods CO2: Students will learn the applications domain decomposition method to solve the elliptic and parabolic problems CO3: Students will learn the stability analysis and error analysis of the various PDEs by domain decomposition methods CO4: Students will also learn the practical applications of the method in time dependent physical and engineering problems	
Unit I: The mathematical Foundation of Domain decomposition Methods. Multi-domain formulation and the Steklov-Poincare Interface Equation, Variational formulation of the multi- domain problem, Iterative Substructuring methods based on transmission conditions at the interface, The Steklov-Poincare equation for Neumann Boundary Value Problems, Iterations on many Subdomains. Unit II: Discretised equations and Domain Decomposition Methods, Finite Element approximations of elliptic equations, Finite Element approximation of the Steklov-Poincare operator, the Schur Complement matrix. Unit III: Iterative Domain Decomposition Methods at the Discrete Level, Iterative Sub- structuring Algorithms, The Schwarz Method, Two-level methods. Unit IV: Domain Decomposition Methods with Time-dependent problems. Multilevel and local grid refinement methods. Text Books 1. Domain Decomposition Methods for Partial Differential Equations, 1999, Alfio Quarteroni and Alberto Valli, Clarendon Press, Oxford. 2. The Finite Element Method for Elliptic Problem, 1989, P. G. Ciarlet, North-Holland Publishing Company, Newyork. Reference Books: 1. Domain Decomposition Methods Algorithms and Theory, 2004, A. Toselli and O. Widlund, Springer-Verlag. 2. Domain Decomposition Methods for the Numerical Solution of Partial Differential Equations, 2008, Tarek P.A. Mathew, Springer-Verlag Berlin Heidelberg. 3. <i>Domain Decomposition: Parallel Multilevel Methods for Elliptic Partial Differential Equations</i>, 1996, B. Smith, P. Bjorstad, W. Gropp, Cambridge.	

AM 631 : Multigrid Methods

Course Code	AM 631
Course Name	Multigrid Methods
L – T – P – C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
CO1: Students will learn the core concepts of multigrid methods with local and global processing. CO2: Students will learn the convergence analysis and classical and advanced relaxation methods CO3: Students will learn the grid refinement algorithms and Fourier analysis of the convergence results.	

CO4: Students will also learn the anisotropic problems and their practical applications.

Unit I: Basic concepts, local and global processing, discretization, 1D model problem and its direct and iterative solution, convergence analysis.

Unit II: 2D model problem, classical relaxation methods, error-smoothing by relaxation, grid-refinement algorithm, two-grid and multigrid algorithm, Fourier analysis of convergence, ellipticity and h-ellipticity.

Unit III: Classical iterative methods, convergence of classical iterative methods, Richardson iteration method, Krylov subspace methods: Generalized minimal residual (GMRES), Conjugate Gradient (CG), Bi-CG method.

Unit IV: Geometric Multigrid Method: Grid transfer, Prolongation and restriction operators, two-level method, Convergence of coarse grid approximation, Smoothing analysis.

Unit V : Multigrid Cycles: V-cycle, W-cycle, F-cycle, convergence of multigrid cycles, remarks on Computational complexity.

Pre-requisites: Good knowledge of Linear Algebra and/or consent from the instructor.

Text Books:

5. A Multigrid Tutorial, 2nd Ed., 2000, E. Henson, and S. F. McCormick, SIAM.
6. Multigrid, 2001, U. Trottenberg, C. W. Oosterlee, A. Schueller, Academic Press.
7. Multigrid Methods, 1982, W. Hackbusch and U. Trottenberg, Springer-Verlag, Berlin.
8. An Introduction to Multigrid Methods, 1992, P. Wesseling, Wiley, Chichester.

Reference Books:

1. Multi-grid Methods and Applications, 1985, W. Hackbusch, Springer, Berlin.
2. Multi-level Adaptive Solutions to Boundary-Value Problems, 1997, Brandt, Math. Comput, Vol. 31, 333-390.
3. An Introduction to Multigrid Methods, 2004, R.T. Edwards, Inc.
4. A Multigrid Tutorial, 2nd Ed., 2000, William L. Briggs, Van Emden Henson, Steve F. McCormick, SIAM.
5. Finite Elements: Theory, Fast Solvers, and Applications in Solid Mechanics, 3rd Ed., 2007, Dietrich Braess, Cambridge University Press.

AM 632 : Introduction to Non-Newtonian Fluids

Course Code	AM 632
Course Name	Introduction to Non-Newtonian Fluids
L – T – P – C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
CO1: The applications areas of non-newtonian fluids are broad and this course could help students to apply the theoretical knowledge into the industrial fields	
CO2: The thermophysical properties of various nanofluids are utilized to enhance the convective heat transport process. Thus, this course could help a student to actively apply such fluids according to their application areas.	
CO3: The solar power collector, and nuclear waste managements are very well utilized such nanofluids that fulfil their aim. Thus, this course can help to choose perfect applicable fluid in these areas	

Course Contents

Kinematics of Fluids Flow: Introduction, Velocity Gradient Tensor, Rate of Deformation Tensor, Analysis of Strain Rates, Spin Tensor, Curvature-Twist Rate Tensor, Objective Tensors, Balance of Mass.

Governing Equations: Introduction, Measure of Mechanical Interactions, Euler's Laws of Motion, Stress and Couple Stress Vectors, Stress and Couple Stress Tensors, Cauchy's Laws of Motion, Analysis of Stress, Energy Balance Equations, Entropy Inequality.

Couple Stress Fluids: Introduction, Constitutive Equations, Equations of Motion, Boundary Conditions, Steady Flow between Parallel Plates, Steady Dimensional Flow between Two Co-axial Cylinders, Poiseuille Flow through Circular Pipes, Creeping Flow Past a Sphere, Some Time- Dependent Flows, Hydromagnetic Channel Flows.

Micro Fluids: Introduction, Description of Micro motion, Kinematics of Deformation, Conservation of Mass, Balance of Moments, Micro Inertia Moments, Balance of Energy, Entropy Inequality, Constitutive Equations for Micro Fluids, Linear Theory of Micro Fluids, Equations of Motions.

Micropolar Fluids: Introduction, Skew-symmetric of the Gyration Tensor and Micro Isotropy, Micropolar Fluids, Thermodynamics of Micropolar Fluids, Equations of Motion, Boundary and Initial Conditions, Two Limiting Cases, Steady Flow between Parallel Plates, Steady Couette Flow between Two Co-axial Cylinders, Pipe Poiseuille Flow, Micropolar Fluids with Stretch.

Text Books

1. An Introduction to Fluid Dynamics, 1976, R. K. Rathy, Oxford & IBH Publishing.
2. Theory of Fluids with Microstructure – An Introduction, 1984, Vijay Kumar Stokes, Springer – Verlag

Reference Books

1. Micropolar Fluids Theory and Applications, 1999, Grzegorz Lukaszewicz, Birkhauser Boston.
2. Fluid Dynamics, 3rd Ed., 2004, William F. Hughes, John A. Brighton, Tata McGraw- Hill.

AM 633 : Bio-Mechanics

Course Code	AM 633
Course Name	<i>Bio-Mechanics</i>
L – T – P – C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
CO1: Students will learn the mathematical aspects of the Bio-mechanics and toll for the investigations in blood flow through the arteries and heart.	
CO2: Students will learn the mass conservation and energy conservation with the momentum conservation in the blood flow problems	
CO3: Students will learn the Rheological properties of bio fluid dynamics concepts	
CO4: Students will also learn the transport phenomena and cardiovascular system.	
Course Contents	

Biomechanics, Method of approach, Tools of investigation, Stresses and rates of strain, Constitutive equations, Newtonian viscous fluid, Hookean elastic solid, Viscoelasticity, Biological transport process, Basic momentum, Heat and mass transport concepts. Conservation laws; mass conservation, Momentum conservation, Energy conservation.

Introduction - Continuum Approach - Blood Flow in Heart, Lung, Arteries and Veins: Introduction - The geometry of the circulation system - Field equations and Boundary conditions, Pulsatile Flow in Arteries - Progressive

The Rheological Properties of Blood Bio-fluid dynamics concept, Transport phenomena and the cardiovascular system.

Biofluid mechanics of organ systems, The lungs, The Kidneys and the liver. Micro-circulation, Pressure distribution in micro vessels, Pressure in the interstitial space, Velocity distribution in micro vessels, The velocity-Hematocrit relationship, mechanics of flow at very low Reynolds numbers.

Text Books:

1. Biomechanics, 1993, Y.C. Fung, Springer-Verlag.
2. Bio-fluid Dynamics, 2003, 1st Ed., Clement Kleinstreuer, CRC Press.

Reference Books:

1. Frontier in Mathematical Biology, 1994, S. A. Levin, Part of the book series: Lecture Notes in Biomathematics (LNBM, volume 100).
2. Biomathematics and Related Computational Problems, 1988, L. M. Ricciardi, Springer.

AM 635 : Finite Elements: Theory and Algorithms

Course Code	AM 635	
Course Name	Finite Elements: Theory and Algorithms	
L – T – P – C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: Students will independently formulate, implement and use various finite element methods for linear and non-linear PDEs and use fundamental PDE in applications. CO2: Students will solve the systems of equations resulting from a finite element method in a numerically efficient manner. CO3: Students will derive common error estimates for finite element methods. CO4: Students will be able to numerically evaluate the efficiency of the finite element method CO5: Students will show the existence and uniqueness for analytical and numerical solutions to elliptic PDEs.		
Course Contents		
Unit I : Review of Lebesgue Integration Theory, Generalized (weak) derivatives, Sobolev norms and associated spaces, inner-product spaces, Hilbert spaces, Trace Theorems		
Unit II : Variational Formulation of Elliptic Boundary Value Problems, Reisz Representation Theorem, The Lax -Milgram Theorem, Formulation of Symmetric Variational Problems, Formulation of Nonsymmetric Variational Problems.		
Unit III: Construction of finite element spaces, Triangular finite elements, two- and three- dimensional finite elements, Rectangular Elements, Interpolation		

Unit IV: Polynomial Approximation Theory, Error Representation, Interpolation Error, Inverse Estimates, A Discrete Sobolev Inequality.	
Unit V: Finite element algorithms and implementation for linear elasticity, Mindlin-Reissner plate problem, Systems in fluid mechanics.	
Pre-requisites: Good knowledge of numerical analysis along with basic programming background and/or consent from the instructor.	
Text Books	
1. The Finite Element Method for Elliptic Problems, 1978, P. G. Ciarlet, North-Holland, Amsterdam, New York, Oxford. 2. Finite Elements: Theory, Fast Solvers, and Applications in Solid Mechanics, 2007, 3rd Ed., Dietrich Braess, Cambridge University Press. 3. Numerical Solution of Partial Differential Equations by the Finite Element Method, 2009, C. Johnson, Dover Publications.	
Reference Books	
1. The Mathematical Theory of Finite Element Methods, 2008, 3rd Ed., Susanne C. Brenner, Ridgway Scott, Springer-Verlag. 2. Finite elements: Theory and Algorithms, 2017, Sashikumaar Ganesan, Lutz Tobiska, Cambridge- IISc Series, Cambridge University Press.	

AM 636 : Cloud Computing

Course Code	AM 636	
Course Name	<i>Cloud Computing</i>	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: Articulate the main concepts, key technologies, strengths, limitations of cloud computing and the possible applications for state-of-the-art cloud computing. CO2: Identify the architecture and infrastructure of cloud computing, including cloud delivery and deployment models. CO3: Identify problems, analyze, and evaluate various cloud computing solutions. CO4: Analyze appropriate cloud computing solutions and recommendations according to the applications used.		
Course Contents		
Unit I: Context: Shared/distributed memory computing; Data/task parallel computing; Role of Cloud computing.		
Unit II: Layers in cloud architecture, Software as a Service (SaaS), features of SaaS and benefits, Platform as a Service (PaaS), features of PaaS and benefits, Infrastructure as a Service (IaaS), features of IaaS and benefits, Service providers, challenges and risks in cloud adoption. Public/Private Clouds; Service-oriented architectures; Mobile, Edge and Fog computing; Multi-clouds.		
Unit III: Application Design Patterns: Workflow and dataflow; Batch, transactional and continuous; Scaling, locality and speedup; Cloud, Mobile and Internet of Things (IoT) applications.		
Unit IV: Execution Models: Synchronous/asynchronous patterns; Scale up/Scale out; Data marshalling/unmarshalling; Load balancing; stateful/stateless applications; Performance metrics; Consistency, Availability, and Partitioning (CAP theorem).		
Unit V: Introduction to Simulator, understanding CloudSim simulator, CloudSim Architecture (User code, CloudSim, GridSim, SimJava) Understanding Working platform for CloudSim		
Text Books		
1. Distributed and Cloud Computing: From Parallel Processing to the Internet of Things, 2011, Kai Hwang, Jack Dongarra, Geoffrey Fox, Morgan Kaufmann.		

2. Cloud computing a practical approach, 2010, Anthony T. Velde, Toby J. Velte Robert Elsenpeter, TATA McGraw- Hill, New Delhi.

Reference Books

1. Cloud Computing: Web-Based Applications That Change the Way You Work and Collaborate Online, 2008, Michael Miller, Que.
2. Cloud computing for dummies, 2010, Judith Hurwitz, Robin Bloor, Marcia Kaufman, Fern Halper, Wiley Publishing, Inc.
3. Cloud Computing (Principles and Paradigms), 2011, Edited by Rajkumar Buyya, James Broberg, Andrzej Goscinski, John Wiley & Sons, Inc.

AM 640 : AI for Medical Image Analysis

Course Code	AM 640	
Course Name	AI for Medical Image Analysis	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: 1. Describe various medical imaging techniques and apply enhancement algorithms including hybrid filters. 2. Illustrate the use of machine learning and deep learning models for medical image processing applications. 3. Apply and compare segmentation techniques such as fuzzy clustering and deep neural networks. 4. Analyze the role of active contour and level set models in medical image boundary detection. 5. Develop AI models for classification and diagnosis of medical images and evaluate them using performance metrics.		
Course Contents Unit I: Introduction to Medical Imaging and AI-Overview of medical imaging modalities, Enhancement- Fundamental Enhancement Techniques, Adaptive Image Filtering, Enhancement by Multiscale Non-linear operators, medical image enhancement with Hybrid filters Unit II: Introduction to machine learning and deep learning for medical imaging, Applications of AI in medical imaging. Unit III: Medical Image Segmentation- Principles and Basic Techniques-Segmentation Strategies, Data Knowledge. Image segmentation by fuzzy clustering, Segmentation with Neural Networks. Unit IV: Active Contours and Surfaces- Explicit Active Contours and Surfaces, The levels set model Unit V: Medical Image Classification and Diagnosis, Classification methods for different imaging modalities, Diagnosis using deep learning models, Evaluation metrics for classification and diagnosis algorithms.		
Text Books 1. Handbook of Medical Imaging-Processing and Analysis, 2nd Ed., 2008, Issac N Bankman, Academic Press. 2. Guide to Medical image Analysis, 2012, Klaus D. Toennies, Springer-Verlag London.		
Reference Books 1. Deep Learning for Medical Image Analysis, 2017, S. Kevin Zhou, Hayit Greenspan, Academic Press. 2. Computer Vision: Algorithms and Applications, 2nd Ed., 2022, Richard Szeliski, Springer.		

AM 642 : Computer Vision with Pattern Recognition

Course Code	AM 642	
Course Name	<i>Computer Vision with Pattern Recognition</i>	
L – T – P - C	3 – 0 – 0 – 3	
Offered as (Compulsory / Elective):	Elective	

Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: 1. Explain image formation, capture, and representation techniques, and apply linear filtering operations such as correlation and convolution. 2. Extract and compare visual features such as edges, corners, blobs, and implement descriptors like SIFT, SURF, HoG, and LBP. 3. Apply visual matching methods including Bag-of-Words, RANSAC, Hough Transform, and optical flow to image and video analysis. 4. Analyze and compare deep learning architectures such as CNNs and RNNs for image and video-based pattern recognition. 5. Evaluate and apply recent learning paradigms such as zero-shot, few-shot, and reinforcement learning in advanced vision applications.	
Course Contents Unit I: Introduction and Overview: Course Overview and Motivation; Introduction to Image Formation, Capture and Representation; Linear Filtering, Correlation, Convolution. Unit II: Visual Features and Representations: Edge, Blobs, Corner Detection; Scale Space and Scale Selection; SIFT, SURF; HoG, LBP, etc. Unit III: Visual Matching: Bag-of-words, VLAD; RANSAC, Hough transform; Pyramid Matching; Optical Flow. Unit IV: Convolutions Neural Networks: Evolution of CNN Architectures: Alexnet, ZFNet, VGG, InceptionNets, ResNets, DenseNets: Recurrent Neural Networks-Review of RNNs; CNN + RNN Models for Video Understanding: Spatio-temporal Models, Action/Activity Recognition. Unit V: Recent Trends: Zero-shot, One-shot, Few-shot Learning; Self-supervised Learning; Reinforcement Learning in Vision; Other Recent Topics and Applications.	
Text Books	
1. Computer Vision: Algorithms and Applications, 2nd Ed., 2022, Richard Szeliski, Springer. 2. Digital Image Processing, 4th Ed., 2017, Rafael C Gonzalez, Richard E Woods, Pearson.	
Reference Books	
1. Computer Vision: Models, Learning, and Inferences, 2012, 1st Ed., Simon J D Prince, Cambridge University. 2. Christopher M. Pattern Recognition and Machine Learning, 2006, Bishop, Springer. 3. Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press.	

AM 644 : Digital Twins

Course Code	AM 644
Course Name	Digital Twins
L – T – P - C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: 1. Describe the architecture, lifecycle, and classification of digital twins. 2. Apply numerical methods to solve ODEs/PDEs in time-domain simulations of dynamical systems. 3. Use simulation tools like MATLAB, Simulink, and COMSOL for digital twin development. 4. Analyze and implement time-domain and frequency-domain models for system simulation. 5. Develop machine learning models (supervised/unsupervised) for data-driven digital twins.	

6. Apply Bayesian inference and Kalman filtering techniques for model updating and uncertainty quantification.
7. Design multi-fidelity and hybrid models combining low- and high-fidelity data.
8. Implement Physics-Informed Neural Networks (PINNs) and grey-box models for systems with incomplete knowledge.
9. Construct deep learning-based digital twins using GANs, VAEs, and surrogate models for real-world applications.
10. Critically evaluate scalability, security, and standardization issues in deploying digital twin technologies.

Unit 1: Introduction to Digital Twins & Computational Foundations

Overview of digital twin technology, Evolution from computational science to digital twins, Role of computational tools in science and engineering, Classification and architecture of digital twins, Numerical methods for ODEs and PDEs, Time-domain simulation of dynamical systems, Tools and platforms for simulation (e.g., MATLAB, Simulink, COMSOL), From model-based to hybrid digital twin frameworks

Unit 2: Frequency and Time Domain Analysis

Frequency domain analysis of dynamical systems, Spectral methods and transfer function approaches, Time domain analysis – state-space modelling and simulation, Comparative study: Time-domain vs Frequency-domain digital twins

Unit 3: Data-Driven Digital Twins

Machine learning and AI in digital twin development, Supervised and unsupervised learning for modelling, Integration of real-time sensor data, Case studies of data-driven digital twin implementations

Unit 4: Bayesian and Probabilistic Methods

Introduction to Bayesian inference, Kalman filters and Extended Kalman filters, Ensemble Kalman filters in digital twin updates, Uncertainty quantification in digital twins

Unit 5: Multi-Scale and Multi-Fidelity Modeling

- Digital twins for multi-timescale dynamical systems, Mixture of Gaussian Processes and Expectation Maximization, Hierarchical and hybrid modeling techniques
- Multi-fidelity modeling: high-fidelity vs low-fidelity data fusion

Unit 6: Physics-Informed and Partially Known Systems

- Handling systems with incomplete physical models, Combining first-principles with data-driven methods, Physics-Informed Neural Networks (PINNs), Grey-box modelling approaches

Unit 7: Deep Learning in Digital Twin Technology

- Deep generative models: GANs and VAEs, Representation learning for high-dimensional systems, Surrogate modeling using deep learning, Case studies: Deep digital twins in healthcare, manufacturing, and energy

Unit 8: Challenges and Future Directions	
Scalability and deployment challenges, Security and privacy concerns in digital twins, Interoperability and standardization, Roadmap for future research and development	
Text Books	
- Ranjan Ganguli, Sandipon Adhikari, Souvik Chakraborty, Mritika Ganguli, Digital Twin- A dynamic system and computing perspective, CRS Press - Khaled, N., Pattel, B., & Siddiqui, A. (2020). <i>Digital twin development and deployment on the cloud: developing cloud-friendly dynamic models using Simulink®/Simscape™ and Amazon AWS</i>. Academic Press. - Farsi, Maryam, et al., eds. "Digital twin technologies and smart cities." (2020). - Chapra, Steven C., and Raymond P. Canale. <i>Numerical methods for engineers</i>. Vol. 1221. New York: McGraw-hill, 2011. - Yang, W. Y., Cao, W., Kim, J., Park, K. W., Park, H. H., Joung, J., ... & Im, T. (2020). <i>Applied numerical methods using MATLAB</i>. John Wiley & Sons. - Strang, Gilbert. <i>Computational science and engineering</i>. Vol. 791. Wellesley, MA: Wellesley-Cambridge Press, 2007. - Karnopp, Dean C., Donald L. Margolis, and Ronald C. Rosenberg. <i>System dynamics: modeling, simulation, and control of mechatronic systems</i>. John Wiley & Sons, 2012. - Barber, David. <i>Bayesian reasoning and machine learning</i>. Cambridge University Press, 2012. - Grewal, Mohinder S., and Angus P. Andrews. <i>Kalman filtering: Theory and Practice with MATLAB</i>. John Wiley & Sons, 2014.	
Reference Books	
- Smith, Ralph C. <i>Uncertainty quantification: theory, implementation, and applications</i>. Society for Industrial and Applied Mathematics, 2024. - Peherstorfer, Benjamin, Karen Willcox, and Max Gunzburger. "Survey of multifidelity methods in uncertainty propagation, inference, and optimization." <i>Siam Review</i> 60.3 (2018): 550-591. - Karniadakis, George Em, et al. "Physics-informed machine learning." <i>Nature Reviews Physics</i> 3.6 (2021): 422-440. - Physics-Informed Neural Networks" (PINNs) – M. Raissi, P. Perdikaris, G. Karniadakis (papers & codes) "Deep Learning" – Ian Goodfellow, Yoshua Bengio, Aaron Courville - Tao, Fei, et al. "Digital twin-driven product design framework." <i>International Journal of Production Research</i> 57.12 (2019): 3935-3953.	

PGC-602 : Personality Development and Communication skills

Course Code	PGC-602	
Course Name	Audit Course	
L – T – P - C	2 – 0- 0 – 0	
Offered as (Compulsory / Elective):	Compulsory	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	PGC/All Departments DIAT	

Unit I: English for Research Paper Writing
 Unit II: Disaster Management
 Unit II: Sanskrit for Technical Knowledge
 Unit IV: Value Education
 Unit V: Constitution of India
 Unit VI: Pedagogy Studies
 Unit VII: Stress Management by Yoga
 Unit VIII: Personality Development through Life Enlightenment Skills

The following listed MOOC/NPTEL courses are found suitable by the Department and can be taken as an elective by the students. However, student may choose other MOOC/NPTEL courses as found relevant to their curriculum with the concurrence of the Programme co-ordinator.

Sl. No.	Course
1	Data Structures and Algorithms Design
2	Advanced Distributed Systems
3	Distributed Optimization and Machine Learning
4	Introduction to Machine Learning
5	Reinforcement Learning
6	Deep Learning for Computer Vision
7	Parameterized Algorithms
8	Applied Accelerated Artificial Intelligence
9	Social Network Analysis
10	The Joy of Computing using Python
11	Deep Learning - IIT Ropar
12	Stochastic Approximation: Theory and Applications
13	Computational Complexity
14	Cyber Security and Privacy
15	Privacy and Security in Online Social Media
16	Responsible & Safe AI Systems
17	Practical Cyber Security for Cyber Security Practitioners
18	Randomized Methods in Complexity
19	Computational Arithmetic - Geometry for Algebraic Curves
20	Secure Computation: Part II
21	Linear Algebra Through Geometry
22	Applied Linear Algebra for Signal Processing, Data Analytics and Machine Learning
23	Multi-Core Computer Architecture
24	Design & Implementation of Human-Computer Interfaces
25	Mathematical Foundations for Machine Learning

26	Statistical Learning for Reliability Analysis
27	Problem Solving through Programming in C
28	Ethical Hacking
29	Programming in Modern C++
30	Introduction to Industry 4.0 and Industrial Internet of Things
31	Introduction to Internet of Things
32	Introduction to Algorithms and Analysis
33	Algorithmic Game Theory
34	Approximation Algorithm
35	Real-Time Systems
36	Second Level Algorithms
37	Artificial Intelligence: Concepts and Techniques
38	Introduction to Large Language Models (LLMs)
39	Pattern Recognition and Application
40	Geographic Information System
41	Application of Forecasting, Regression and Time Series Models
42	Approximate Reasoning using Fuzzy Set Theory
43	Real Analysis II
44	Mathematical Methods and its Applications
45	Essential Mathematics for Machine Learning
46	Introduction to Fuzzy Set Theory, Arithmetic and Logic
47	Introduction to Methods of Applied Mathematics
48	Matrix Computation and its Applications
49	Computational Commutative Algebra
50	Excelling with Mathematical Modeling
51	Foundations of R Software (In Hindi Language)
52	Geometry of Curves and Surfaces
53	A Basic Course in Number Theory
54	Ordinary Differential Equations
55	A Primer to Mathematical Optimization
56	Category Theory
57	Introduction to Algebraic Geometry
58	Partial Differential Equations - IITB
59	An introduction to Point-Set-Topology Part - II
60	Galois Theory
61	Linear Algebra
62	An Introduction to Smooth Manifolds

63	Introductory Course in Real Analysis
64	Rings and Modules

M.Tech. in Data Science

Introduction: M. Tech. (Modelling & Simulation) programme and M.Tech (Data Science) programme were offered under the Department of Applied Mathematics. The Department of Applied Mathematics came into existence with the inception of Institute of Armament Studies in 1953 as Faculty of Applied Mathematics. The faculty constituted of three departments: (1) Applied Mathematics (2) Ballistics (3) Statistics. In 1991 the three departments merged into one and named it as Department of Applied Mathematics.

The faculty of the department have been actively involved in the research in different fields of applied mathematics such as ballistics, flight dynamics, hydro-dynamics, hydro-ballistics, Numerical Methods and Optimization, Statistics, Probability, Neural Network, Fuzzy Logic and Genetic Algorithm, Parallel Computing, Cryptography and Machine Learning, Deep Learning, IoT, Cyber Security, Computer Networks etc.

This MTech. (Data Sciences) programme is of two years duration where the student undergoes basic training in the subjects(Core and Elective) related to **probability and statistics, inference, regression, optimization, statistical simulation and data analysis, sampling theory (Math and Statistics); management decision analysis, decision models, game theory (IME, Economics), programming, algorithms, operating systems, databases, signal processing, image processing, machine learning and data mining techniques of data science (CS, EE). Information Theory (information, entropy, conditional information, coding), Multi-resolution (multi-rate) signal processing (wavelets, pyramids), ANN, SVM, Projection pursuit Artificial Intelligence and DSS** through classroom teaching in the first and second year. During this period the student is also exposed to various simulation tools and practical. The second year is the dissertation phase where the student works under the guidance of a recognized guide on a problem related to Data Science. Course curriculum will be updated periodically to keep pace with contemporary technological advancement.

Program Outcomes (POs) :

PO1:	Apply mathematical principles for data analysis and visualization for analysing and processing the data.

PO2:	Ability to carry out research and development for solving real world problems using data science tools and techniques.
PO3:	Ability to work with industry, government, DRDO, Tri-services and PSUs to contribute to the social and economic development by using their expertise in Data Science.

Why Data Science: Data science is concerned with the acquisition, storage, retrieval, processing and finally the conversion of data into knowledge where the quantum of data is very large. Experiments, observations, and numerical simulations in many areas of science and business are currently generating terabytes (2^{40} bytes) of data, and in some cases are on the verge of generating petabytes (2^{50} bytes) and beyond. Today we have been witnessing to an exponential growth of the volume of data produced and stored. This can be explained by the evolution of the technology that results in the proliferation of data with different formats from the most various domains (e.g., health care, banking, government or logistics) and sources (e.g., sensors, social networks or mobile devices). Facebook, for example, has an average of 4.75 billion pieces of content shared among friends every day. Business is generating enormous quantities of data that are too big to be processed and analyzed by the traditional Relational Database Management Systems (RDBMSs) and Data Warehouses (DWs) technologies, which are struggling to meet the performance and scalability requirements. Therefore, in the recent years, a new approach that aims to mitigate these limitations has emerged. Companies like Facebook, Google, Yahoo and Amazon etc. are the pioneers in creating solutions as well as recruiting technologies to deal with these “Big Data” scenarios. Adopting Big Data-based technologies not only mitigates the problems presented above, but also opens new perspectives that allow extracting value from Big Data. Big Data-based technologies are being applied with success in multiple scenarios like in: (1) e-commerce and marketing, the crowds do on the web allow identifying trends that improve campaigns, evaluate personal profiles of a user, so that the content shown is the one he will most likely enjoy; (2) government and public health, allowing the detection and tracking of disease outbreaks via social media or detect frauds; (3) transportation, industry and surveillance, with real-time improved estimated times of arrival and smart use of resources.

Data science is concerned with the acquisition, storage, retrieval, processing and finally the conversion of data into knowledge where the quantum of data is very large. Two current disciplines that have strong overlap with data science are computer science and statistics. An important difference between Data Science and Computer Science is that Data science heavily uses the more continuous aspects of mathematics together with considerable statistics. In order to handle voluminous data (ranging from terabytes to petabytes) in various forms (structured, semi-structured, unstructured formats and from

different sources) of different Veracity (managing the reliability and predictability of inherently imprecise data types will be challenging) and its complexity (relationships, hierarchies, and multiple data linkages will have to be connected and correlated), a systematic approach is required before meaningful output expected from the data collected or received.

Basic four steps which are adapted in Data Science are:

- **Data Collection:** Proliferation of smart devices, sensors, web, mobile and social media has led to explosive amount of complex data. To make use of this data, one needs expertise in Internet of Things and Databases to effectively collect and manage such huge volumes of data.
- **Data Processing:** The next step is to convert the raw data into forms that can be scientifically analyzed, which includes data cleaning and transformation. For example, by transforming social network data into graph data, one can use concepts from Graph Theory to analyze social network data. To process huge volumes of data, one needs expertise in Databases, High Performance Computing and mainly Statistics. The data one needs to handle is a heterogeneous mix of different types of data, such as images, videos, text, social networks, etc. To handle these different types of data one needs expertise in areas such as Image and Video Analytics, Information Retrieval, Social Media Analytics, etc.
- **Data Analysis:** The third step is to analyze the processed data using various Statistical, Data Mining and Machine Learning algorithms. Most of the existing data analysis algorithms do not scale to large datasets. As a result, one needs expertise in Statistics, Data Mining and High Performance Computing to design systems that can efficiently analyze large volumes of complex data.
- **Data Product:** The final step is to make decisions from the data analysis and also deliver the analyzed information to the world in the form of various data products. This is often done using data visualization techniques, which are integrated with various smart devices. This step requires expertise in Information Visualization, Databases and Computer Networks.

Two current disciplines that have strong overlap with data science are computer science and statistics. An important difference between Data Science and Computer Science is that Data science heavily uses the more continuous aspects of mathematics together with considerable statistics. Data Science is the combination of statistics, mathematics, programming, problem-solving, capturing data in ingenious ways, the ability to look at things differently, and the activity of cleansing, preparing and aligning the data.

Eligibility Criteria for Admission to join in this programme

M. Tech Data Sciences	The candidate must have a Valid GATE Score and marks / CPI (Cumulative Performance Index), referred to in subsequent section, implies a minimum of 55% marks/SPI of 5.5 (on a 10-point scale) as long as it is at least seven percent higher than the minimum pass marks/CPI from a recognized Institute / University in B. Tech / BE degree (OR) MSc / MS degree in CS / IT / Mathematics/ Statistics / Physics / Electronics, Provided 1) Mathematics is one of the subject at the graduate level and 2) Valid GATE Score in CSE / IT / ECE / ME / AE / CE / EE / IN / MA / ST / PH /DA 3). For Self-financed and Sponsored candidates GATE is exempted.

CSE - Computer Science Engineering

IT - Information Technology

AE - Aerospace Engineering

ECE - Electronics & Communication Engineering

ME - Mechanical Engineering

CE – Civil Engineering

EE – Electrical Engineering

IN – Instrumentation Engineering

MA- Mathematics

ST- Statistics

DA- Data Science and Artificial Intelligence

PH - Physics

Semester I:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 604	Advanced Statistical Techniques	3	0	3
2.	AM 605	Linear Algebra and Applications	3	0	3
3.	AM 608	Data Structures and Algorithms	3	0	3
4.	AM 610	Data Analysis and Visualization	3	0	3
5.		Elective 1	3	0	3
6.	AM 609L	Data Science: Tools & Techniques (LAB)	0	6	3
7.	PGC-601	Research Methodology and IPR	2	0	2
		TOTAL	17	6	20

Semester II:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 623	Machine Learning	3	0	3

2.	AM 624	Big Data Analytics	3	0	3
3.		Elective I	3	0	3
4.		Elective II	3	0	3
5.		Elective III	3	0	3
6.	AM 620L	Machine Learning and Deep Learning (LAB)	0	6	3
7.	PGC-602	Audit Course	2	0	0
		TOTAL	17	6	20

Semester III:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 651	Dissertation & Seminar Phase – I	40**		20
		TOTAL	40		20

Semester IV:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
8.	AM 652	Dissertation & Seminar Phase – II	40**		20
		TOTAL	40		20

* 1 Credit for Theory (or Tutorial) means 1 contact hour in a week and 1 credit for practical means 2 contact hours in a week.

**Contact Hours per week Note: During non teaching days, Internship / Industrial Tour will be accepted for all students relevant to the dissertation work especially Modeling and Simulation.

List of Electives are given below:

Few of the elective courses are listed below. However, Students are allowed to choose Elective Course(s) from various M. Tech programmes offering by the respective departments which are as per the DIAT PG Course of Study Book / updates of the course curriculum time to time.

Sl. No.	Course Code	Course
1	AM 603	Optimization Techniques
2	AM 625	Image and Video Analytics
3	AM 627	Information Theory and Coding
4	AM 628	Computational Number Theory and Cryptography

5	AM 635	Finite Elements: Theory and Algorithms
6	AM 636	Cloud Computing
7	AM 637	Generative AI
8	AM 638	Reinforcement Learning
9	AM 639	Deep Learning for Computer Vision
10	AM 640	AI for Medical Image Analysis
11	AM 641	Accelerated Computing
12	AM 642	Computer Vision with Pattern Recognition
13	AM 643	Database Systems
14	AM 644	Digital Twins
15	CE 631	Deep Learning
16	CE 632	Computer Vision
17	CE 691	Secure Wireless Sensor Networks
18	CE 699	Internet of things

AM 603 : Optimization Techniques

Course Code	AM 603
Course Name	Optimization Techniques
L – T – P - C	3 – 0 - 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	AUTUMN
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: CO1: Understand the application of various optimization techniques that can help to make decisions for practical problems in industries and apply basic concepts of mathematics to formulate an optimization problem. CO2: Understand the importance of optimization of industrial process management with the theory of optimization methods and algorithms developed for solving various types of optimization problems. CO3: Analyze and appreciate the variety of performance measures for various optimization problems such as Sensitivity analysis, Risk analysis and Portfolio Management, etc. CO4: Implement, develop and promote research interest in applying optimization techniques in problems of Engineering and Technology. And the mathematical results and numerical techniques of optimization theory to concrete Engineering problems.	
Course Contents Linear programming: Simplex method, Two-phase method, Big-M method, Duality, Integer linear Programming, Dynamic Programming, Sensitivity analysis.	

Assignment problem: Hungarian's algorithm, Degeneracy, applications, unbalanced problems, traveling salesman problem. Classical optimization techniques: Single variable optimization with and without constraints, multi-variable optimization without constraints, multi-variable optimization with constraints – method of Penalty methods Lagrange multipliers, Kuhn-Tucker conditions. Numerical methods for optimization: Minimization and maximization of convex functions- Local & Global optimum- Convergence-Speed of convergence. One dimensional minimization - Elimination methods: Fibonacci & Golden section search - Gradient methods - Steepest descent method, Nelder Mead's Simplex search method, methods of line search; Quasi-Newton methods: DFP, BFGS. CPM/PERT: Simulation of CPM/PERT network, Analysis of an activity network, Simulation of inventory system and manufacturing system.
Text Books
4. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India. 5. Engineering Optimization: Theory and Practice, 4th Ed., 2009, S.S. Rao, Wiley Eastern Ltd. 6. Optimization: Theory and Practice, 2004, MC Joshi, KM Moudgalya, Narosa.
Reference Books
9. Mathematical Programming Techniques, 3rd Ed., 1991, N. S. Kambo, East-West Press, New Delhi. 10. An Introduction to Optimization, 2nd Ed., 2001, Chong, E. k. and Zak, S. H., Wiley India. 11. Linear and Nonlinear Programming, 3rd Ed., 2008, Luenberger, D. G. and Ye, Y., Springer. 12. Mathematical Programming Techniques, 1997, Kambo, N.S., East-West Press. 13. Introduction to Optimization, 1988, Beale, John Wiley. 14. Numerical Methods and Optimization, Hari Arora, S.K. Kataria & Sons 15. Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer 16. Nonlinear Programming Theory and Algorithms, 1979, Bazarra M.S., Sherali H.D. & Shetty C.M., John Wiley, New York.

AM 604 : Advanced Statistical Techniques

Course Code	AM 604
Course Name	Advanced Statistical Techniques
L – T – P - C	3 – 0 - 0 – 3
Offered as (Compulsory / Elective):	Compulsory
Offered in (SPRING / AUTUMN)	AUTUMN
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: CO1: Understand the fundamental concepts of probability and statistics such as Axioms, addition law, conditional probability, Baye's principle etc., and their real-life application to predict the data. CO2: Understand the importance of Probability Distributions such as Binomial, Poisson, Normal and Exponential Distributions and their properties and problems on special probability distributions. CO3: Analyze and appreciate the statistical theory behind Curve fitting, regression modeling and Chi Square Test, student test & Fisherman test. CO4: Understand the theory behind Design and Analysis of Experiments: Need for conducting Experiments, and their possible applications.	

Course Contents	
Probability Theory: Sample Spaces- Events - Axioms – Counting - Conditional Probability and Bayes’ Theorem – The Binomial Theorem – Random variable and distributions: Mean and Variance of a Random Variable-Binomial-Poisson-Exponential and Normal distributions. Sampling Distributions & Descriptive Statistics: The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population, Sampling distributions (Chi-Square, t, F, z). Test of Hypothesis- Testing for Attributes –Mean of Normal Population – One-tailed and two-tailed tests, F-test and Chi-Square test - - Analysis of variance ANOVA – One way and two-way classifications. Introduction to Statistical modelling. Regression modeling for Normal response and quantitative explanatory: Introduction to Statistical modelling, Variables, Simple and Multiple regressions, Model building and validation Comparison of regressions. Stochastic process: Basic idea of random processes, Stationary, Markov processes, Markov chains and applications, Introduction to ergodicity.	
Text Books	
4. Stochastic Process, 3rd Ed., 2010, J. Medhi, New Age Science Ltd. 5. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Academic Press. 6. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.	
Reference Books	
9. All of Statistics: A Concise Course in Statistical Inference, 2003, Larry Wasserman, Springer. 10. Introduction to Statistical Modelling, 2010, W. J. Krzanowski, Oxford university press. 11. Schaum’s outlines Probability and statistics, 4th Ed., 2013, Murray R. Spiegel, John Schiller, R Alu Srinivasan, Tata McGraw Hill 12. Learning R, O’Reilly, 2013, Richard Cotton. 13. Introductory statistics with R, 2008, Dalgaard, Peter Springer Science & Business Media. 14. A Handbook of Statistical Analysis Using R, Second Edition LLC, 2014, Brain S. Everitt. 15. Introduction to Probability and Statistics for Engineers and Scientists”, 4th Ed., 2009, Sheldon M. Ross, Academic Press. 16. R Cookbook, O’Reilly, 2011, Paul Teetor.	

AM 605 : Linear Algebra and Applications

Course Code	AM 605	
Course Name	Linear Algebra and Applications	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Compulsory	
Offered in (SPRING / AUTUMN)	AUTUMN	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: Students will build the fundamentals of linear algebra CO2: Students appreciate the applications of different matrix decomposition methods CO3: Students can correlate the related applications of linear algebra CO4: Students should be in a position to formulate the relevant real-world problems using the understanding of linear algebra		
Course Contents		
Unit I: Introduction to Fundamental Linear Algebra Problems and Their Importance, Linear Transformations, Linear Variety, Range Space and Rank, Null Space and Nullity, Homomorphism, Matrix of Linear Transformations, Matrix Representation of a linear transformation, Structure of the solutions of the matrix equation $Ax = b$, Change of bases. Unit II: Matrix and vector norms, floating points arithmetic, forward and backward stability of algorithms, conditioning of a problem, perturbation analysis, solving linear systems, Gaussian elimination, LU factorization, Pivoting, Cholesky		

decomposition, Iterative refinement, QR factorization, Gram-Schmidt orthogonalization, Projections, Householder reflectors, Givens rotation.

Unit III: Singular Value Decomposition, Rank and matrix approximations, image compression using SVD, Least squares and least norm solution of linear systems, pseudoinverse, normal equations, Eigenvalue problems, Gershgorin theorem, Similarity transform, Eigenvalue & eigenvector computations and sensitivity, Power method, Schur decomposition, QR iteration with & without shifts, Hessenberg transformation, Rayleigh quotient, Symmetric eigenvalue problem, Computing the Singular Value Decomposition, Golub-Kahan-Reinsch algorithm, Chan SVD algorithm, Krylov subspace methods: Lanczos, Arnoldi, MINRES, GMRES, Conjugate Gradient.

Text Books

3. Iterative Methods for Sparse Linear Systems, 2nd Ed., 2003, Y. Saad, SIAM.
4. Introduction to Linear Algebra, 6th Ed., 2023, Gilbert Strang, Wellesley-Cambridge Press.

Reference Books

7. Fundamentals of Matrix Computations, 2nd Ed., 2002, D. S. Watkins, John-Wiley.
8. Numerical Linear Algebra and Applications, 2nd Ed., 2010, B. N. Datta, SIAM.
9. Applied Numerical Linear Algebra, 1997, J. W. Demmel, SIAM.
10. An Introduction to numerical linear algebra, 1994, C. G. Cullen, Charles PWS Publishing.
11. Linear Algebra and its Applications, 2013, C. Lay David, Pearson.
12. Matrix Computation, 1996, G. Golub, C. F. Van Loan, John Hopkins

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AM 608 : Data Structures and Algorithms

Course Code	AM 608
Course Name	Data Structures and Algorithms
L – T – P – C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Compulsory
Offered in (SPRING / AUTUMN)	AUTUMN
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: 1. Analyze the time and space complexity of algorithms using asymptotic notations. 2. Implement and manipulate linear and non-linear data structures effectively. 3. Apply appropriate searching and sorting algorithms to solve data processing problems. 4. Design efficient algorithms using greedy, divide and conquer, and dynamic programming paradigms. 5. Solve complex real-world problems using advanced graph algorithms and optimize their performance.	

Course Contents	
Preliminaries: Concept & notation, common operation on data structures, algorithm complexity, time space trade-off between algorithm, physical & logical representation of different data structures. Arrays: Arrays defined, representing arrays in memory, Various operation (traversal, insertion, deletion), Multidimensional arrays, Sequential allocation, Address calculation, Sparse arrays. List: Simple Array Implementation of Lists, Linked Lists, Doubly Linked Lists, Circularly Linked list. Stack: Stack Model, Implementation of Stacks, Applications of Stacks. Queue: Queue Model, Array Implementation of Queues, Applications of Queues. Trees: Implementation Of Trees, Tree Traversal with an application, Binary Trees-Implementation, Expression trees, Binary Search Tree, Binary Search Trees, Various Operations On BST- Make Empty, Find, Find Min and Find Max, Insert, Delete, Average-Case Analysis, AVL Trees- Single Rotation, Double Rotation, B-trees. Hashing: Definition, Hash Function, Separate Chaining, Open Addressing- Linear Probing, Quadratic Probing, Double Hashing, Rehashing, Extendible Hashing. Priority Queues: Model, Simple Implementation, Binary Heap-Structure Property, Heap Order Property, Basic Heap Operation, Application of Priority Queues- The Selection Problem, Event Simulation, Heap Sorting: Preliminaries, Insertion Sort- Algorithm, Analysis of Insertion Sort, Shell sort- Analysis Of Shell sort, Heapsort- Analysis of Heapsort, Merge sort- Analysis of Merge sort, Quicksort- Picking the Pivot, Partitioning Strategy, Small Arrays, Analysis of Quicksort, Bucket Sort. Graphs: Definitions, Representation of Graphs, Topological Sort, Shortest Path Algorithms- Unweighted Shortest Paths, Dijkstra's Algorithm, Graph with Negative Edge Costs, Acyclic Graphs, All- Pairs Shortest, Minimal Spanning Tree- Prim's Algorithm, Kruskal's Algorithm, Application of Depth First Search- Undirected Graphs, Biconnectivity, Euler Circuits, Directed Graphs. Algorithm Design Techniques: Greedy Algorithms- A Simple Scheduling Problem, Huffman Codes, Divide and Conquer Running Time of Divide and Conquer Algorithms, Closets-Points Problem, The Selection Problem	
Text Books	
1. Introduction to Algorithms, 4 th Ed., 2022, Thomas H. Cormen, Charles E. Leiserson, The MIT Press. 2. Data Structures and Algorithms in Java, 4 th Ed., 2004, M. Goodrich, R. Tamassia, John Wiley and Sons, Inc.	
Reference Books	
2. An Introduction to Data Structures with Applications, 1986, Jean Paul Tremblay, Paul G. Sorenson, Tata McGraw Hill. 3. Data Structures & Program Design, 1 st Ed., 1998, Robert L. Kruse, Pearson.	

AM 609 : Data Science: Tools and Techniques

Course Code	AM 609
Course Name	Data Science: Tools and Techniques
L – T – P - C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Elective
Offered in (SPRING / AUTUMN)	AUTUMN
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: CO1: Understand the fundamental concepts of data science and terminology. CO2: Understand the fundamental concepts of data science process and machine learning concepts. CO3: Understand the fundamental concepts of tools used in data science. CO4: Fundamental concepts of large data & Data Visualization. CO5: To implement the aspects of Data Science through case studies.	

Programming Language: Introduction to Python, Programming Interfaces, Spyder, Python script file, Print Message to Standard Output, variables and data types, Reading Input from console, Type Conversion, Arithmetic Operators and Conditions Control Flow - Relational Operators, if...else statement, if...else if...else statement, Logical operators, While Loops, break and continue statement, Loops with else statement, pass statement, Python for loop, Range Function, Lists: Creating List, Accessing elements from List, Inserting and Deleting Elements from List, List Slicing, Joining two list, Repeating sequence, Nested List, Built-in List Methods and Functions, Searching elements in List, Sorting elements of List Python Data Structures: Python Set, Creating Set, Adding/Removing elements to/from set, Python Set Operations: Union, Intersection, Difference and Symmetric Difference, Python Tuple, Creating Tuple, Understanding Difference between Tuple and List, Accessing Elements in Tuple, Python Dictionary, Creating Dictionary, Accessing / Changing / Deleting Elements in Dictionary Data Pre-processing Numpy, Dask, Xarray: Numpy, Creating Numpy array, Numpy data type, Accessing Elements in Numpy, Element wise calculations, Vectorized Operation, Numpy Subsetting, Built-in Methods of Numpy, Array creation Methods: arange, linspace, eye, Numpy 2D Array, 2D Array Indexing, Matrix Calculations , Dask, Parallel computing with Dask, Xarray integration with Dask Pandas: Reading Files, Writing Files, Loading Data with Pandas, Selecting Specific Columns, Selecting rows using labels: loc, Selecting rows using position: iloc, Adding and Removing rows and Columns, Filtering Data Frames, Importing Data from csv Files, Missing Data Handling, OnHot Encoder, Label Encoding, Data Splitting, Training Data, Importance of Test Data. Built-in Dictionary Methods and Functions: Data Analytics, Data preprocessing, Analyzing data, Handling missing data, Applying Machine learning techniques to analyze data Functions: Defining Functions in Python, Function Argument, Single Parameter Functions, Function Returning single Values, Functions with multiple parameters, Function that return Multiple Values, Functions with Default arguments, Named arguments, Scope and Lifetime of Variables, Global specifier Data Visualization with Matplotlib, Seaborn: Introduction to Matplotlib, Basic Plotting with Matplotlib, Line Plot on Example DataSet, Exploring the plot Options, Other types of Plots, Bar Plot, Pie Plot, Histograms Regression for data analysis: Introduction to regression and Classification, Types of Classification, Simple Linear regression Intuition, Sci kit Learn Library, Hands on Lab on Simple Linear Regression, Performance Evaluation Regression and Classification Part 2: Multivariable Linear regression, Handson Example on Multivariable LR, Performance Evaluation, Improving the Performance, Backward Elimination method, Other types of Regression Models, Performance Evaluation of different Regression Models Classification in Machine Learning : Classification Introduction, K-Nearest Neighbours, Decision Tress, Naïve Bayes algorithm, Introduction to Neural Networks
Text Books
- Mastering Python for Data Science, 2015, Samir Madhavan, Packt Publishing. - Python Machine Learning, 2015, Sebastian Raschka Packt Publishing. - Python Basics: A Self-Teaching Introduction, 2018, H. Bhasin, Mercury Learning and Information. - Beginning Python, 2008, Magnus Lie Hetland, Apress Berkeley, CA.
Reference Books
- Michael Roberts Beginning Python, 2005, Peter Norton, Alex Samuel, David Aitel, Eric Foster-Johnson, Leonard Richardson, Jason Diamond, Aleatha Parker, Wiley Publishing. - Expert Python Programming: Best practices for designing, coding, and distributing your Python software Tarek Ziadé, 2008, Packt Publishing. - Programming Python, 2010, Mark Lutz, O'Reilly Media. - Programming in Python 3: A Complete Introduction to the Python Language, 2010, Mark Summerfield, Addison-Wesley. - Practical programming: An introduction to computer science using Python, 2009, Jennifer Campbell, Paul Gries, Jason Montojo, Greg Wilson, Pragmatic Bookshelf. - Core Python Programming, 2nd Ed., 2006, Wesley Chun, Prentice Hall. - Core Python Applications Programming, 2012, Wesley J Chun, Prentice Hall.

15. Programming Computer Vision with Python: Tools and algorithms for analyzing images, 2012, Jan Erik Solem, O'Reilly Media.

AM 610 : Data Analysis and Visualization

Course Code	AM 610	
Course Name	Data Analysis and Visualization	
L – T – P - C	3 – 0 – 0 – 3	
Offered as (Compulsory / Elective):	Compulsory	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: Understand the concepts of Data Analytics and Data Types. CO2: Learn different hypothesis testing techniques and data transformation techniques. CO3 Perform feature scaling, anomaly detection and augmentation on data. CO4: Handle large scale analytics from various domains. CO5: Apply cluster analysis for decision support systems.		
Course Contents Unit I : Introduction to data analytics, Data Types, Feature Engineering, Data Pipelines, Preliminary Data Analysis, DA: exploratory data analysis, bar chart, histogram, box plot, scatter plot, heat map and contour map, parallel coordinates, radar plot. Unit II: Data pre-processing, data representation, machine learning for data processing, visualization pipeline, vector field visualization, applications to biological and medical data, visualization toolkit, linear models. Unit III: Data Cleaning and Transformation, Handling Missing Values, mean/median, kNN, model-driven imputation, Transforming feature types and feature values, OHE: one hot encoding, normalization, log-transform. Unit IV: Feature scaling, Anomaly detection, data augmentation, high-leverage points, collinearity, high dimensions, Curse of dimensionality, intelligibility, computational efficiency, distance functions, principal components, clustering, multidimensional scaling, information visualization. Unit V: Introduction to Cluster Analysis, Classification and Regression Trees (CART).		
Text Books		
1.Python for data analysis: Data wrangling with Pandas, NumPy, and IPython, 2012, W. McKinney, O'Reilly Media, Inc.		
Reference Books		
1. Information Visualization: Perception for Design, 2 nd Ed., 2004, C. Ware, Morgan Kaufmann. 2. A Byte of Python: Python Tutorial, 2003, C. H. Swaroop. 3. Business Statistics for Contemporary Decision Making, 4 th Ed., 2003, Ken Black, John Wiley & Sons, Inc. 4. Statistics for Business and Economics : Cengage Learning, 13 th Ed., 2011, Anderson Sweeney Williams. 5. Applied Statistics & Probability for Engineering, 2002, Douglas C. Montgomery, George C. Runger, John Wiley & Sons, Inc. 6. Probability and Statistics for Engineering and the Sciences : Cengage Learning, 2011, Jay L. Devore. 7. Applied logistic regression (Wiley Series in probability and statistics), 2000, David W. Hosmer, Stanley Lemeshow, Wiley-Interscience Publication. 8. Data Mining: Concepts and Techniques, 3 rd Ed., 2006, Jiawei Han and Micheline Kamber. 9. 9.Finding Groups in Data: An Introduction to Cluster Analysis, 1990, Leonard Kaufman, Peter J. Rousseeuw, John Wiley & Sons, Inc.		

10. 10.Data Pipelines Pocket Reference: Moving and Processing Data for Analytics, 2021, James Densmore. O'Reilly.
11. 11.Designing Data-Intensive Applications: The Big Ideas Behind Reliable, Scalable, and Maintainable Systems, 2017, Martin K, O'Reilly.
12. 12.Visualization Handbook, 2004, C .D. Hansen, C. R. Johnson, Academic Press, 2004.

PGC-601 : Research Methodology and IPR

Course Code	PGC-601	
Course Name	Research Methodology and IPR	
L – T – P – C	2 – 0- 0 – 2	
Offered as (Compulsory / Elective):	Compulsory	
Offered in (SPRING / AUTUMN)	AUTUMN	
Offered by (Name of Department/ Centre)	PGC/All Departments DIAT	
Course Outcomes: After completing this course, the students will be able to: CO1: Understanding the fundamentals of research and its methodology CO2: Choose the appropriate research design and develop appropriate research hypothesis for a research project CO3: Knowledge of manuscript preparation, patents and Intellectual property CO4: Technology transfer and application of IPR in various domains.		
Course Contents Unit I : Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations Unit II : Effective literature studies approaches, analysis Plagiarism, Research ethics, Unit III : Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee Unit IV : Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. Unit V : Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications Unit VI : New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.		
Texts / References		
10. Research methodology: an introduction for science & engineering students, Stuart Melville and Wayne Goddard. 11. Research Methodology: An Introduction, Wayne Goddard and Stuart Melville. 12. Research Methodology: A Step-by-Step Guide for beginners, 2 nd Ed., Ranjit Kumar. 13. Resisting Intellectual Property, 2007, Halbert, Taylor & Francis Ltd. 14. Industrial Design, 1992, Mayall, McGraw Hill. 15. Product Design, 1974, Niebel, McGraw Hill. 16. Introduction to Design, 1962, Asimov, Prentice Hall. 17. Intellectual Property in New Technological Age, 2016, Robert P. Merges, Peter S. Menell, Mark A. Lemley. 18. Intellectual Property Rights Under WTO, 2008, T. Ramappa, S. Chand.		

AM 623 : Machine Learning

Course Code	AM 623

Course Name	Machine Learning
L – T – P – C	3 – 0 – 0 – 3
Offered as (Compulsory / Elective):	Compulsory
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: 6. Explain the core concepts of machine learning, types of learning paradigms, and issues in designing learning systems. 7. Apply supervised learning algorithms such as linear regression, decision trees, SVMs, and neural networks for prediction and classification tasks. 8. Implement unsupervised learning techniques like k-means, GMM, EM, and hierarchical clustering to discover hidden patterns in data. 9. Analyze the bias-variance tradeoff, evaluate model complexity using VC dimension, and select appropriate models using performance metrics and cross-validation techniques. 10. Demonstrate the ability to implement and evaluate machine learning models using Python for real-world datasets.	
Course Contents UNIT I - Well-posed learning problems, Designing a learning system, Perspectives and issues in machine learning. Types of Machine Learning-Supervised, Unsupervised, Reinforcement learning. UNIT II- Supervised Learning Algorithms- Regression and Classification-Linear, Polynomial- Regularization, Regression based on Normal Equations, Instance-based learning-Decision Trees, Artificial Neural Networks Support Vector Machines, Support Vector Regression UNIT III- Unsupervised learning- k-means, Gaussian Mixture Models, Expectation Maximization, Hierarchical clustering, Spectral clustering. UNIT IV: Bias variance trade-off, VC dimension, Model selection, AUC-ROC, Metrics-Regression, Classification, Clustering, K Fold cross-validation. UNIT V: Python Implementation of Regression, Classification, and Clustering Algorithms.	
Text Books	
5. Machine Learning, Indian Ed., 2017, Tom M. Mitchell, Tata McGraw Hill Education. 6. Machine Learning: An Algorithmic Perspective, 2 nd Ed., 2014, Stephen Marsland, Taylor & Francis (CRC). 7. Machine Learning, A probabilistic perspective, 2012, Kevin Murphy, MIT Press. 8. Hands on Machine Learning with Scikit-Learn, Keras & TensorFlow, O'Reilly- 3 rd Edition, 2022	
Reference Books	
1 Pattern Recognition and Machine Learning, 2006, Christopher M. Bishop, Springer. 2. Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press.	

AM 624 : Big Data Analytics

Course Code	AM 624
Course Name	Big Data Analytics
L – T – P – C	3 – 0 – 0 – 3

Offered as (Compulsory / Elective):	Compulsory
Offered in (SPRING / AUTUMN)	SPRING
Offered by (Name of Department/ Centre)	Department of Applied Mathematics
Course Outcomes: After completing this course, the students will be able to: CO1: Understand the building blocks of Big Data CO2: Articulate the programming aspects of cloud computing(map Reduce etc) CO3: Understand the specialized aspects of big data with the help of different big data application CO4: Represent the analytical aspects of Big Data CO5: Know the recent research trends related to Hadoop File System, MapReduce and Google File System etc	
Course Contents Unit I :Introduction to Big Data: Types of Digital Data-Characteristics of Data – Evolution of Big Data – Definition of Big Data – Challenges with Big Data – 3Vs of Big Data – Non Definitional traits of Big Data – Business Intelligence vs. Big Data – Data warehouse and Hadoop environment – Coexistence. Big Data Analytics: Classification of analytics – Data Science – Terminologies in Big Data – CAP Theorem – BASE Concept. NoSQL: Types of Databases – Advantages – NewSQL – SQL vs. NOSQL vs NewSQL. Introduction to Hadoop: Features – Advantages – Versions – Overview of Hadoop Eco systems – Hadoop distributions – Hadoop vs. SQL – RDBMS vs. Hadoop – Hadoop Components – Architecture – HDFS – Map Reduce: Mapper – Reducer – Combiner – Partitioner – Searching – Sorting – Compression. Hadoop 2 (YARN): Architecture – Interacting with Hadoop Eco systems. Unit II: No SQL databases: Mongo DB: Introduction – Features – Data types – Mongo DB Query language – CRUD operations – Arrays – Functions: Count – Sort – Limit – Skip – Aggregate – Map Reduce. Cursors – Indexes – Mongo Import – Mongo Export. Cassandra: Introduction – Features – Data types – CQLSH – Key spaces – CRUD operations – Collections – Counter – TTL – Alter commands – Import and Export – Querying System tables. Unit III: Hadoop Eco systems: Hive – Architecture – data type – File format – HQL – SerDe – User defined functions – Pig: Features – Anatomy – Pig on Hadoop – Pig Philosophy – Pig Latin overview – Data types – Running pig – Execution modes of Pig – HDFS commands – Relational operators – Eval Functions – Complex data type – Piggy Bank – User defined Functions – Parameter substitution – Diagnostic operator. Jasper Report: Introduction – Connecting to Mongo DB – Connecting to Cassandra – Introduction to Machine learning: Linear Regression – Clustering – Collaborative filtering – Association rule mining – Decision tree. Unit IV: Algorithms for massive data sets, Algorithms for SISD, SIMD environments, Linked Big Data Analysis – Graph Computing and Network Science, Big Data Visualization, Big Data Mobile Applications Unit V: Applications for massive data sets: Finding similar items, mining data streams, page rank algorithm, link analysis, mining social-network graphs, semantic analysis, study of applications of big spatial-temporal data, social media data, scientific data and others.	
Text Books	
4. Big Data Fundamentals: Concepts, Drivers & Techniques 2016 by Thomas Erl, Wajid Khattak, Paul Buhler, Publisher: Prentice Hall, 2016), Service Tech Press 5. Seema Acharya, Subhashini Chellappan, “Big Data and Analytics”, Wiley Publication, 2015. 6. Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006	
Reference Books	
10. Introduction To Algorithms, 3rd Ed., 2009, Thomas H. Cormen, Charles E. Leiserson, Ronaldo L. Rivest, Clifford Stien, The MIT Press. 11. Big Data for Dummies, 2013, Judith Hurwitz, Alan Nugent, Dr. Fern Halper, Marcia Kaufman, John Wiley & Sons, Inc. 12. Hadoop: The Definitive Guide, 2012, Tom White, O’Reilly Publications. 13. Mongo DB in Action, 2012, Kyle Banker, Manning Publications Company.	

14. Mining of Massive Datasets, 2012, Jure Leskovec, Anand Rajaraman and Jeffrey David Ullman, Cambridge University Press.
15. Big Data Analytics, 2015, Seema Acharya, Subhasini Chellappan, Wiley.
16. Big Data Fundamentals: Concepts, Drivers & Techniques, 2016, Thomas Erl, Wajid Khattak, Paul Buhler, Prentice Hall, Service Tech Press.
17. Data Mining, 2nd Ed., 2006, Jiawei Han & Micheline Kamber, Elsevier.

AM 625 : Image and Video Analytics

Course Code	AM 625	
Course Name	Image and Video Analytics	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: understand basic image model, and will learn basic image processing techniques to analyze the image in terms of histogram, contrast, sharpness, etc. CO2: learn different image enhancement techniques, and also understand the factors which degrades the quality of an image, and also learns the image restoration techniques. Different spatial filtering operations for image enhancement will be learnt along with the morphological operations. CO3: learn image segmentation algorithms, understands the need for image compression and learn the spatial and frequency domain techniques used for image compression. CO4: learn different feature extraction techniques employed for image analysis and recognition, and gets an overview on applications of image processing in Machine vision		
Course Contents Digital Image Fundamentals: Introduction – Origin –Steps in Digital Image Processing –Components; Elements of Visual Perception – Light and Electromagnetic Spectrum – Image Sensing and Acquisition – Image Sampling and Quantization – Relationships between pixels. Image Enhancement: Spatial Domain: Gray level transformations – Histogram processing – Basics of Spatial Filtering–Smoothing and Sharpening Spatial Filtering – Frequency Domain: Introduction to Fourier Transform – Smoothing and Sharpening frequency domain filters – Ideal, Butterworth and Gaussian filters. Image Restoration: Noise models – Mean filters – Order Statistics – Adaptive filters – Band reject – Band pass – Notch – Optimum notch filtering – Inverse Filtering – Constrained Least Square Filtering – Wiener filtering. Morphological image processing: Dilation, Erosion, Opening, Closing, Applications to; Boundary extraction, Region filling, Extraction of connected components. Image Compression: Fundamentals – Image Compression models – Error Free Compression – Variable Length Coding –Bit – Plane Coding – Lossless Predictive Coding – Lossy Compression – Lossy Predictive Coding –Wavelet Coding – Compression Standards – JPEG2000. Image Segmentation and Representation: Segmentation – Detection of Discontinuities – Edge Linking and Boundary detection – Region based segmentation; Representation – Boundary descriptors – Simple Descriptors – Shape numbers –Regional descriptors – Simple and Topological Descriptors – Introduction to Image Processing Toolbox – Practice of Image Processing Toolbox – Case studies–Various Image Processing Techniques. Object recognition: Decision-theoretic methods. SVM, feature selection methods, feature extraction methods, Maximum Output Information (MOI) for joint selection and classifier training. Colour models and Transformations – Image and Video segmentation - Image and video demonising- Image and Video enhancement- Image and Video compression. Object detection and recognition in image and video - Texture models Image and Video classification models- Object tracking in Video		
Text Books 3. Digital Image Processing, 3rd Ed., 2007, R. C. Gonzalez, Richard E. Woods, Prentice Hall. 4. Digital Image Processing Using MATLAB, 2nd Ed., 2009, R. C. Gonzalez, Richard E. Woods, Steven L. Eddins, Gatesmark Publishing.		

Reference Books	
8.	Digital Picture Processing, 2nd Ed., 1982, A. Rosenfeld, A. C. Kak, Academic Press.
9.	Fundamentals of Digital Image Processing, 1st Ed., 1989, A.K. Jain, Prentice Hall of India.
10.	Pattern Classification and Scene Analysis, 1973, R. O. Duda, P. E. Hart, John Wiley.
11.	Pattern Recognition, Applications to Large Data-Set Problems, 1984, Sing-Tze Bow, Marcel Dekker.
12.	Computer Vision: Algorithms and Applications, 2011, Rick Szelisk, Springer.
13.	Intelligent Video Surveillance Systems, 2013, Jean-Yves Dufour, Wiley.
14.	Video Analytics for Business Intelligence, 2012, Caifeng Shan, Fatih Porikli, Tao Xiang, Shaogang Gong, Springer.

AM 627 : Information Theory and Coding

Course Code	AM 627		
Course Name	Information Theory and Coding		
L – T – P - C	3 – 0 - 0 – 3		
Offered as (Compulsory / Elective):	Elective		
Offered in (SPRING / AUTUMN)	SPRING		
Offered by (Name of Department/ Centre)	Department of Applied Mathematics		
Course Outcomes: After completing this course, the students will be able to: CO1: learn the channel performance using Information theory. CO2: Comprehend various error control code properties CO3: Apply linear block codes for error detection and correction CO4: Apply convolution codes for performance analysis & cyclic codes for error detection and correction. CO5: Design BCH & RS codes for Channel performance improvement against burst errors.			
Course Contents Information Theory: Uncertainty, Information, Entropy, Discrete Memoryless Channel, Mutual Information, Channel Capacity, Shannon’s Theorems, Gaussian Channel, Limits to Communication Linear Block Codes: Groups, Fields and Vector Spaces, Construction of Galois Fields of Prime Order, Syndrome Error Detection, Standard Array and Syndrome Decoding, Hamming Codes Cyclic Codes: Polynomial Representation of Code words, Generator Polynomial, Systematic Codes, Generator Matrix, Syndrome Calculation and Error Detection, Decoding of Cyclic Codes Structure and Properties of Convolutional Codes: Convolutional Encoder Representation, Tree, Trellis, and State Diagrams, Distance Properties of Convolutional Codes, Punctured Convolutional Codes and Rate Compatible Schemes Decoding of Convolutional Codes: Maximum Likelihood Detection, The Viterbi Algorithm Automatic Repeat Request Strategies: Basic Techniques, Hybrid ARQ Introduction to Cryptography: History. Overview of cryptography, Simple classical cryptosystems, Cryptanalysis Perfect Secrecy: Information theoretic security, One time pad Secret and Public Key Encryption: Description of DES, Description of AES (advanced encryption standard), Trapdoor Function, The RSA Algorithm			
Text Books			
1. Essentials of Error-Control Coding, 2006, Jorge Castiñeira Moreira, Patrick Guy Farrell, John Wiley. 2. Information and Coding Theory, 2000, G. A. Jones and J. M. Jones, Springer. 3. History of Cryptography and Cryptanalysis Codes, Ciphers, and Their Algorithms, 2018, John F. Dooley, Springer.			
Reference Books			

1. Number Theory, Elementary Cryptography and Codes, 2009, Maria Welleda Baldoni, Ciro Ciliberto, Giulia Maria Piacentini Cattaneo, Springer.
2. Essentials of Error-Control Coding, 2006, Jorge Castiñeira Moreira, Patrick Guy Farrell, John Wiley & Sons Ltd.
3. Essentials of Error-Control Coding Techniques, 1990, Hideki Imai, Academic Press, Inc.
4. Codes and Cryptography, 1988, Dominic Welsh, Oxford Science Publications.
5. Elements of information theory, 2nd Ed., 2006, T. M. Cover, J. A. Thomas, Wiley-Interscience.
6. Coding and information theory, 1980, R. W. Hamming, Prentice Hall Inc.
7. Entropy and Information Theory, 2nd Ed., 2011, Robert M. Gray, Springer, 2011.

AM 628 : Computational Number Theory and Cryptography

Course Code	AM 628		
Course Name	Computational Number Theory and Cryptography		
L – T – P - C	3 – 0 - 0 – 3		
Offered as (Compulsory / Elective):		Elective	
Offered in (SPRING / AUTUMN)		SPRING	
Offered by (Name of Department/ Centre)		Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: learn computational methods in Algebra and Number Theory. CO2: understand fundamental number-theoretic algorithms such as the Euclidean algorithm, the Chinese Remainder algorithm, binary powering, and algorithms for integer arithmetic. CO3: understand the number-theoretic foundations of modern cryptography and the principles behind their security. CO4: Understand the mathematical foundations for security of modern cryptography, asymmetric crypto-systems based on hard computational problems from Algebra and Number Theory. CO5: apply fundamental algorithms for symmetric key and public-key cryptography.			
Course Contents Introduction: Introduction to Cryptosystems, Classical Ciphers, Cryptanalysis of Classical ciphers, LFSR based stream ciphers. Shannon’s Theory, Diffie-Helman Key Exchange, Rabin Cryptosystem, Knapsack Ciphers, Digital Signature, Secret Sharing, ElGamal Cryptosystem Number Theory: Divisibility: Representations of Integers, Computer Operations with Integers, Complexity of Integer Operations, Divisibility, Prime Numbers, The Fundamental Theorem of Arithmetic, Sieve of Eratosthenes, The Distribution of Primes, Greatest Common Divisor, Euclidean Algorithm, Mersenne Numbers, Fermat Numbers, Perfect numbers Congruence: Congruences, Congruence Applications, Linear Congruences, The Chinese Remainder Theorem, Theorems of Fermat and Euler- Fermat, Wilson’s Theorem, Pseudo Primes, Carmichael Numbers, The Euler Phi-Function, The Sum and Number of Divisors, Quadratic Residue, Quadratic Reciprocity. Legendre and Jacobi Symbols, Computing Legendre symbols, Primitive Roots, Quadratic Reciprocity Law, Inter Factorization and Primality Testing Algorithms: Complexity of Number Theoretic Algorithms, Fermat’s Factorization, Kraitchik’s Improvement, Trial division, Pollard Rho Algorithm, p-1 method, CFRAC method, quadratic sieve method, elliptic curve method. Primality testing algorithms: Fermat test, Miller-Rabin test, Solovay-Strassen test, AKS test. Computing discrete logarithms over finite fields: Baby-step-giant-step method, Pollard rho method, Pohlig-Hellman method, index calculus methods, linear sieve method, Coppersmith's algorithm. Representation of finite fields: Groups, Fields, Finite Fields, Arithmetic in Finite Field, Finding Multiplicative Inverses in finite fields, Prime and extension fields, representation of extension fields, polynomial basis, primitive elements, normal basis, optimal normal basis, irreducible polynomials. Binary Fields and their application in Cryptosystems.			

Elliptic Curve Cryptography: Introduction to Elliptic Curves, the elliptic curve group, elliptic curves over finite fields, Schoof's point counting algorithm, Discrete Log problem for Elliptic curves, Factorization using Elliptic Curve, Advantage of Elliptic Curve Cryptography over other Public Key Cryptosystems.

Text Books

1. **Introduction to Modern Cryptography, 2nd Ed., 2008, J. Katz, Y. Lindell, Chapman & Hall/CRC. Computational number theory, 2018, Abhijit Das, Chapman and Hall/CRC.**

2. A Course in Number Theory and Cryptography, 2006, N. Koblitz, Springer.

3. An Introduction to theory of numbers, 2006, I. Niven, H.S. Zuckerman, H.L. Montgomery, John Wiley & Sons, Inc.

Reference Books

10. Elliptic curves: number theory and cryptography, 2003, L. C. Washington, Chapman & Hall/CRC.
11. Rational Points on Elliptic Curves, 2005, J. Silverman, J. Tate, Springer-Verlag.
12. Guide to elliptic curve cryptography, 2004, D. Hankerson, A. Menezes, S. Vanstone, Springer-Verlag.
13. An Introduction to Mathematical Cryptography, 2008, J. Pipher, J. Hoffstein, J. H. Silverman, Springer-Verlag.
14. Elementary Number Theory, 1998, G. A. Jones, J. M. Jones, Springer-Verlag.
15. An Introduction to Cryptography, 2001, R. A. Mollin, Chapman & Hall.
16. Number Theory for Computing, 2nd Ed., 2002, Song Y. Yan, Springer-Verlag.
17. Introduction to Algorithms, Second Edition, 1994, T. H. Cormen, C. E. Leiserson, R. L. Rivest, Prentice Hall of India.
18. Elementary Theory of Numbers, 5th Ed., 2004, K. Rosen, Addison Wesley.
19. Factorization and Primality Testing, 1989, D. M. Bressoud, Springer-Verlag.
20. A computational introduction to number theory and algebra, 2009, V. Shoup, Cambridge University Press.
21. Mathematics for computer algebra, 1992, M. Mignotte, Springer-Verlag.
22. An introduction to the theory of numbers, 2011, I. Niven, H. S. Zuckerman, H. L. Montgomery, John Wiley.
23. Modern computer algebra, 3rd Ed., 2013, J. Von zur Gathen, J. Gerhard, Cambridge University Press.
24. Introduction to finite fields and their applications, 2012, R. Lidl, H. Niederreiter, Cambridge University Press.
25. Applications of finite fields, 1993, A. J. Menezes, Kluwer Academic Publishers.
26. Rational points on elliptic curves, 2015, J. H. Silverman, J. Tate, Springer International Edition.
27. Guide to elliptic curve cryptography, 2004, D. R. Hankerson, A. J. Menezes, S. A. Vanstone, Springer-Verlag.
28. Public-key cryptography: Theory and practice, 2009, A. Das, C. E. Veni Madhavan, Pearson Education Asia.
29. A course in computational algebraic number theory, 1993, H. Cohen, Springer-Verlag.

AM 635 : Finite Elements: Theory and Algorithms

Course Code	AM 635		
Course Name	Finite Elements: Theory and Algorithms		
L – T – P - C	3 – 0 - 0 – 3		
Offered as (Compulsory / Elective):	Elective		
Offered in (SPRING / AUTUMN)	SPRING		
Offered by (Name of Department/ Centre)	Department of Applied Mathematics		
Course Outcomes: After completing this course, the students will be able to:			
CO1: Students will independently formulate, implement and use various finite element methods for linear and non-linear PDEs and use fundamental PDE in applications.			
CO2: Students will solve the systems of equations resulting from a finite element method in a numerically efficient manner.			

CO3: Students will derive common error estimates for finite element methods.
CO4: Students will be able to numerically evaluate the efficiency of the finite element method
CO5: Students will show the existence and uniqueness for analytical and numerical solutions to elliptic PDEs.
Course Contents Unit I : Review of Lebesgue Integration Theory, Generalized (weak) derivatives, Sobolev norms and associated spaces, inner-product spaces, Hilbert spaces, Trace Theorems Unit II : Variational Formulation of Elliptic Boundary Value Problems, Reisz Representation Theorem, The Lax -Milgram Theorem, Formulation of Symmetric Variational Problems, Formulation of Nonsymmetric Variational Problems. Unit III: Construction of finite element spaces, Triangular finite elements, two- and three- dimensional finite elements, Rectangular Elements, Interpolation Unit IV: Polynomial Approximation Theory, Error Representation, Interpolation Error, Inverse Estimates, A Discrete Sobolev Inequality. Unit V: Finite element algorithms and implementation for linear elasticity, Mindlin-Reissner plate problem, Systems in fluid mechanics. Pre-requisites: Good knowledge of numerical analysis along with basic programming background and/or consent from the instructor.
Text Books 1. The Finite Element Method for Elliptic Problems, 1978, P. G. Ciarlet, North-Holland, Amsterdam, New York, Oxford. 2. Finite Elements: Theory, Fast Solvers, and Applications in Solid Mechanics, 2007, 3 rd Ed., Dietrich Braess, Cambridge University Press. 3. Numerical Solution of Partial Differential Equations by the Finite Element Method, 2009, C. Johnson, Dover Publications.
Reference Books 1. The Mathematical Theory of Finite Element Methods, 2008, 3 rd Ed., Susanne C. Brenner, Ridgway Scott, Springer-Verlag. 2. Finite elements: Theory and Algorithms, 2017, Sashikumaar Ganesan, Lutz Tobiska, Cambridge- IISc Series, Cambridge University Press.

AM 636 : Cloud Computing

Course Code	AM 636	
Course Name	Cloud Computing	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to:		
CO1: Articulate the main concepts, key technologies, strengths, limitations of cloud computing and the possible applications for state-of-the-art cloud computing.		
CO2: Identify the architecture and infrastructure of cloud computing, including cloud delivery and deployment models.		
CO3: Identify problems, analyze, and evaluate various cloud computing solutions.		
CO4: Analyze appropriate cloud computing solutions and recommendations according to the applications used.		

Course Contents	
Unit I: Context: Shared/distributed memory computing; Data/task parallel computing; Role of Cloud computing.	
Unit II: Layers in cloud architecture, Software as a Service (SaaS), features of SaaS and benefits, Platform as a Service (PaaS), features of PaaS and benefits, Infrastructure as a Service (IaaS), features of IaaS and benefits, Service providers, challenges and risks in cloud adoption. Public/Private Clouds; Service-oriented architectures; Mobile, Edge and Fog computing; Multi-clouds.	
Unit III: Application Design Patterns: Workflow and dataflow; Batch, transactional and continuous; Scaling, locality and speedup; Cloud, Mobile and Internet of Things (IoT) applications.	
Unit IV: Execution Models: Synchronous/asynchronous patterns; Scale up/Scale out; Data marshalling/unmarshalling; Load balancing; stateful/stateless applications; Performance metrics; Consistency, Availability and Partitioning (CAP theorem).	
Unit V: Introduction to Simulator, understanding CloudSim simulator, CloudSim Architecture(User code, CloudSim, GridSim, SimJava) Understanding Working platform for CloudSim	
Text Books	
3. Distributed and Cloud Computing: From Parallel Processing to the Internet of Things, 2011, Kai Hwang, Jack Dongarra and Geoffrey Fox, Morgan Kaufmann. 4. Cloud computing a practical approach, 2010, Anthony T.Velte , Toby J. Velte Robert Elsenpeter, TATA McGraw-Hill, New Delhi.	
Reference Books	
4. Cloud Computing: Web-Based Applications That Change the Way You Work and Collaborate Online, 2008, Michael Miller, Que. 5. Cloud computing for dummies, 2010, Judith Hurwitz, Robin Bloor, Marcia Kaufman, Fern Halper, Wiley Publishing, Inc. 6. Cloud Computing (Principles and Paradigms), 2011, Rajkumar Buyya, James Broberg, Andrzej Goscinski, John Wiley & Sons, Inc.	

AM 637 : Generative AI

Course Code	AM 637	
Course Name	Generative AI	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to:		
1. 2. 3. 4. 5. Explain the principles and types of generative models, including probabilistic approaches and ethical considerations. Design and implement autoencoders and variational autoencoders for data representation and generation tasks. Develop and train GAN models and their variants, and address common training challenges. Apply reinforcement learning techniques to enhance generative model performance and support unsupervised learning. Evaluate and implement generative AI solutions in real-world scenarios involving text, images, audio, and video synthesis.		

Course Contents	
Unit I : Introduction to Generative AI : What is generative AI?, Types of generative models, Applications of generative AI, Probabilistic Models: Introduction to probability theory, Bayesian networks, Markov random fields.	
Unit II: Autoencoders : Basics of autoencoders, Variational autoencoders (VAEs), Autoencoder-based generative models. Generative Adversarial Networks (GANs): Basics of GANs, Training and evaluating GANs, GAN-based generative models	
Unit III: Deep Generative Models : Introduction to deep generative models, Deep Boltzmann Machines (DBMs), Deep Belief Networks (DBNs), Adversarial attacks on generative models, Neural Ordinary Differential Equations (ODEs)	
Unit IV: Reinforcement Learning for Generative Models : Basics of reinforcement learning, Policy gradients, Reinforcement learning for generative models, and Generative models for unsupervised learning.	
Unit V: Applications of Generative AI-Image generation, Text generation, Music generation, Video generation	
Text Books	
1. Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press. 2. Generative Deep Learning, 2019, David Foster. O'Reilly.	
Reference Books	
1. Probabilistic Graphical Models, 2009, Daphne Koller and Nir Friedman, MIT Press. 2. Pattern Recognition and Machine Learning, 2006, Christopher M. Bishop, Springer.	

AM 638 : Reinforcement Learning

Course Code	AM 638	
Course Name	Reinforcement Learning	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: Understand the kind of problems that can be solved using the RL CO2: Build the fundamentals needed for understanding RL CO3: Learn the advance topics in the area of Deep Reinforcement learning CO4: Exposure to the frameworks and libraries for implementing RL CO5: Develop the RL algorithms in the area of Gaming, Robotics and Self driving cars		
Course Contents		
Unit I : Introduction to reinforcement learning, Basic concepts and terminology, Markov decision processes (MDPs), Value functions and policies. Dynamic programming and Monte Carlo methods: Policy evaluation and improvement, Value iteration and policy iteration, Monte Carlo methods for policy evaluation		
Unit II: Temporal difference learning : TD(0) and Sarsa algorithms, Q-learning algorithm, Function approximation with TD learning. Policy gradient methods: Gradient ascent algorithms, REINFORCE algorithm, Actor-critic algorithms.		
Unit III: Exploration and exploitation: Epsilon-greedy and softmax policies, Upper confidence bound (UCB) algorithm, Thompson sampling. Deep reinforcement learning: Deep Q-networks (DQN), Double DQN and Dueling DQN, Policy gradient methods with deep neural networks.		
Unit IV: Multi-agent reinforcement learning Decentralized and centralized policies, Markov games and Nash equilibria Cooperative and competitive multi-agent learning		
Unit V: Applications of reinforcement learning: Robotics and control, Game playing and strategy, Natural language processing and dialogue systems, Advanced topics in reinforcement learning		
Text Books		
1. Reinforcement Learning, 2 nd Ed., 2018, Richard S Sutton, Andrew G Barto, MIT Press.		

2. Reinforcement Learning and Stochastic Optimization, 2022, Warren B Powell, Wiley.

Reference Books

1. Algorithms for Reinforcement Learning, 1st Ed., 2010, Csaba Szepesvarim Morgan, Claypool Publisher.
2. Grokking Deep Reinforcement Learning, 2020, Miguel Morales, Manning Publisher.

AM 639 : Deep Learning for Computer Vision

Course Code	AM 639	
Course Name	Deep Learning for Computer Vision	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: Learn the fundamental principles of deep learning. CO2: Understand various methods for Deep Learning in computer vision. CO3: Identify the deep learning algorithms for various types of learning tasks in various domains. CO4: Implement deep learning algorithms and solve real-world problems.		
Course Contents Unit I : Introduction: Basic introduction on Computer Vision, Feed forward Neural networks, Gradient descent and the back propagation algorithm, Unit saturation, the vanishing gradient problem, and ways to mitigate it. Unit II: ReLU Heuristics for avoiding bad local minima, Heuristics for faster training, Nestors accelerated gradient descent, Regularization, Dropout. Convolutional Neural Networks: Architectures, convolution / pooling layers, Recurrent Neural Networks: LSTM, GRU, Encoder Decoder architectures. Unit III: Deep Unsupervised Learning: Autoencoders, Variational Auto-encoders, Adversarial Generative Networks, Auto-encoder and DBM Attention and memory models. Dynamic memory networks, Applications of Deep Learning to Computer Vision: Image segmentation, object detection, automatic image captioning, Unit IV: Image generation with Generative adversarial networks, video-to-text with LSTM models, and Attention models for computer vision tasks.		
Text Books		
1 Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press.		
Reference Books		
1. The Elements of Statistical Learning, 2 nd Ed., 2009, T. Hastie, R. Tibshirani, J. Friedman, Springer. 2. Probabilistic Graphical Models, 2009, D. Koller, and N. Friedman, MIT Press.		

AM 640 : AI for Medical Image Analysis

Course Code	AM 640	
Course Name	AI for Medical Image Analysis	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to:		

- Describe various medical imaging techniques and apply enhancement algorithms including hybrid filters. - Illustrate the use of machine learning and deep learning models for medical image processing applications. - Apply and compare segmentation techniques such as fuzzy clustering and deep neural networks. - Analyze the role of active contour and level set models in medical image boundary detection. - Develop AI models for classification and diagnosis of medical images and evaluate them using performance metrics.
Course Contents Unit I : Introduction to Medical Imaging and AI-Overview of medical imaging modalities, Enhancement- Fundamental Enhancement Techniques, Adaptive Image Filtering, Enhancement by Multiscale Non-linear operators, Medical image enhancement with Hybrid filters Unit II: Introduction to machine learning and deep learning for medical imaging, Applications of AI in medical imaging. Unit III: Medical Image Segmentation- Principles and Basic Techniques-Segmentation Strategies, Data Knowledge. Image segmentation by fuzzy clustering, Segmentation with Neural Networks. Unit IV: Active Contours and Surfaces- Explicit Active Contours and Surfaces, The levels set model Unit V: Medical Image Classification and Diagnosis, Classification methods for different imaging modalities, Diagnosis using deep learning models, Evaluation metrics for classification and diagnosis algorithms.
Text Books
- Handbook of Medical Imaging-Processing and Analysis, 2nd Ed., 2008, Issac N Bankman, Academic Press. - Guide to Medical image Analysis, 2012, Klaus D. Toennies, Springer-Verlag London.
Reference Books
- Deep Learning for Medical Image Analysis, 2017, S. Kevin Zhou, Hayit Greenspan, Academic Press. - Computer Vision: Algorithms and Applications, 2nd Ed., 2022, Richard Szeliski, Springer.

AM 641 : Accelerated Computing

Course Code	AM 641	
Course Name	Accelerated Computing	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: Understand the various computing platforms including GPU and CPU CO2: Learn about different frameworks for implementation of Accelerated Artificial Intelligence CO3: Analyse the use of different learning concepts like transfer learning, distributed learning, federated learning etc. CO4: Apply knowledge representation with accelerated artificial intelligence.		
Course Contents Unit I : Introduction to System Hardware CPU, RAM, GPU, Interconnects, Storage, Network Controller; Introduction to GPU Accelerators, Introduction to System Software Operating System, Virtualization, Cloud, Introduction to Containers and IDE Unit II: Design principles for building High Performance compute clusters; Implementation details for building High Performance compute clusters for AI, Frameworks for Accelerated Deep Learning Workloads Unit III: Optimizing Deep Learning Training: Automated Mixed Precision, Transfer Learning, Fundamentals of Distributed Computing.		

Unit IV: Challenges with Distributed Deep Learning, Fundamentals of Accelerating Deployment, Accelerated Data Analytics
Unit V: Scale Out with DASK; Web visualizations to GPU accelerated cross-filtering Accelerated ETL Pipeline with SPARK
Text Books
1. Accelerating AI with Synthetic Data, 2020, Khaled El Emam, O'Reilly Media, Inc.
Reference Books
1. Accelerated Optimization for Machine Learning, 1 st Ed., 2020, Zhouchen Lin Huan Li, Springer.

AM 642 : Computer Vision with Pattern Recognition

Course Code	AM 642	
Course Name	Computer Vision with Pattern Recognition	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to:		
6. Explain image formation, capture, and representation techniques, and apply linear filtering operations such as correlation and convolution. 7. Extract and compare visual features such as edges, corners, blobs, and implement descriptors like SIFT, SURF, HoG, and LBP. 8. Apply visual matching methods including Bag-of-Words, RANSAC, Hough Transform, and optical flow to image and video analysis. 9. Analyze and compare deep learning architectures such as CNNs and RNNs for image and video-based pattern recognition. 10. Evaluate and apply recent learning paradigms such as zero-shot, few-shot, and reinforcement learning in advanced vision applications.		
Course Contents		
Unit I : Introduction and Overview: Course Overview and Motivation; Introduction to Image Formation, Capture and Representation; Linear Filtering, Correlation, Convolution		
Unit II: Visual Features and Representations: Edge, Blobs, Corner Detection; Scale Space and Scale Selection; SIFT, SURF; HoG, LBP, etc		
Unit III: Visual Matching: Bag-of-words, VLAD; RANSAC, Hough transform; Pyramid Matching; Optical Flow		
Unit IV: Convolutions Neural Networks: Evolution of CNN Architectures: Alexnet, ZFNet, VGG, InceptionNets, ResNets, DenseNets: Recurrent Neural Networks-Review of RNNs; CNN + RNN Models for Video Understanding: Spatio-temporal Models, Action/Activity Recognition		
Unit V: Recent Trends: Zero-shot, One-shot, Few-shot Learning; Self-supervised Learning; Reinforcement Learning in Vision; Other Recent Topics and Applications		
Text Books		
3. Computer Vision: Algorithms and Applications, 2nd Ed., 2022, Richard Szeliski, Springer. 4. Digital Image Processing, 4th Ed., 2017, Rafael C Gonzalez and Richard E Woods, Pearson.		
Reference Books		

4. Computer Vision: Models, Learning, and Inferences, 1st Ed., 2012, Simon J D Prince, Cambridge University.
5. M. Pattern Recognition and Machine Learning, 2006, Christopher Bishop, Springer.
6. Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press.

AM 643 : Database Systems

Course Code	AM 643	
Course Name	Database Systems	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Compulsory	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: CO1: Demonstrate the basic elements of a relational database management system CO2: Identify the data models for relevant problems CO3: Design entity relationship and convert entity relationship diagrams into RDBMS and formulate SQL queries on the respect data CO4: Apply database storage structures and access techniques		
Course Contents Unit I : Data base System Applications, Purpose of Database Systems, View of Data – Data Abstraction Instances and Schemas – data Models – the ER Model – Relational Model – Other Models – Database Languages – DDL – DML – database Access for applications Programs – data base Users and Administrator – Transaction Management – data base Architecture – Storage Manager – the Query Processor Data base design and ER diagrams – ER Model - Entities, Attributes and Entity sets – Relationships and Relationship sets – ER Design Issues – Concept Design – Conceptual Design for University Enterprise. Introduction to the Relational Model – Structure – Database Schema, Keys – Schema Diagrams Unit II: Relational Query Languages, Relational Operations. Relational Algebra – Selection and projection set operations – renaming – Joins – Division – Examples of Algebra overviews – Relational calculus – Tuple relational Calculus – Domain relational calculus. Overview of the SQL Query Language – Basic Structure of SQL Queries, Set Operations, Aggregate Functions – GROUPBY – HAVING, Nested Sub queries, Views, Triggers. Unit III: Normalization – Introduction, Non loss decomposition and functional dependencies, First, Second, and third normal forms – dependency preservation. Higher Normal Forms - Introduction, Multi-valued dependencies and Fourth normal form Unit IV: Transaction Concept- Transaction State- Implementation of Atomicity and Durability – Concurrent – Executions – Serializability- Recoverability – Implementation of Isolation – Testing for serializability- Lock –Based Protocols – Timestamp Based Protocol. Unit V: File organization:– File organization – various kinds of indexes. Query Processing – Measures of query cost - Selection operation – Projection operation, - Join operation		
Text Books 1. Data base System Concepts, 7 th Ed., 2019, A. Silberschatz, H. F. Korth, S. Sudarshan, McGraw hill. 2. Data base Management Systems, 3 rd Ed., 2002, Raghurama Krishnan, Johannes Gehrke, TATA McGrawHill.		
Reference Books 1. Fundamentals of Database Systems, 7 th Ed., 2017, Elmasri Navathe, Pearson Education. 2. An Introduction to Database systems, 8 th Ed., 2003, C. J. Date, A. Kannan, S. Swami Nadhan, Pearson.		

AM 644 : Digital Twins

Course Code	AM 644	
Course Name	Digital Twins	
L – T – P - C	3 – 0 - 0 – 3	
Offered as (Compulsory / Elective):	Elective	
Offered in (SPRING / AUTUMN)	SPRING	
Offered by (Name of Department/ Centre)	Department of Applied Mathematics	
Course Outcomes: After completing this course, the students will be able to: 11. Describe the architecture, lifecycle, and classification of digital twins. 12. Apply numerical methods to solve ODEs/PDEs in time-domain simulations of dynamical systems. 13. Use simulation tools like MATLAB, Simulink, and COMSOL for digital twin development. 14. Analyze and implement time-domain and frequency-domain models for system simulation. 15. Develop machine learning models (supervised/unsupervised) for data-driven digital twins. 16. Apply Bayesian inference and Kalman filtering techniques for model updating and uncertainty quantification. 17. Design multi-fidelity and hybrid models combining low- and high-fidelity data. 18. Implement Physics-Informed Neural Networks (PINNs) and grey-box models for systems with incomplete knowledge. 19. Construct deep learning-based digital twins using GANs, VAEs, and surrogate models for real-world applications. 20. Critically evaluate scalability, security, and standardization issues in deploying digital twin technologies.		

Unit 1: Introduction to Digital Twins & Computational Foundations

Overview of digital twin technology, Evolution from computational science to digital twins, Role of computational tools in science and engineering, Classification and architecture of digital twins, Numerical methods for ODEs and PDEs, Time-domain simulation of dynamical systems, Tools and platforms for simulation (e.g., MATLAB, Simulink, COMSOL), From model-based to hybrid digital twin frameworks

Unit 2: Frequency and Time Domain Analysis

Frequency domain analysis of dynamical systems, Spectral methods and transfer function approaches, Time domain analysis – state-space modelling and simulation, Comparative study: Time-domain vs Frequency-domain digital twins

Unit 3: Data-Driven Digital Twins

Machine learning and AI in digital twin development, Supervised and unsupervised learning for modelling, Integration of real-time sensor data, Case studies of data-driven digital twin implementations

Unit 4: Bayesian and Probabilistic Methods

Introduction to Bayesian inference, Kalman filters and Extended Kalman filters, Ensemble Kalman filters in digital twin updates, Uncertainty quantification in digital twins

Unit 5: Multi-Scale and Multi-Fidelity Modeling

- Digital twins for multi-timescale dynamical systems, Mixture of Gaussian Processes and Expectation Maximization, Hierarchical and hybrid modeling techniques
- Multi-fidelity modeling: high-fidelity vs low-fidelity data fusion

Unit 6: Physics-Informed and Partially Known Systems	
Handling systems with incomplete physical models, Combining first-principles with data-driven methods, Physics-Informed Neural Networks (PINNs), Grey-box modelling approaches	
Unit 7: Deep Learning in Digital Twin Technology	
Deep generative models: GANs and VAEs, Representation learning for high-dimensional systems, Surrogate modeling using deep learning, Case studies: Deep digital twins in healthcare, manufacturing, and energy	
Unit 8: Challenges and Future Directions	
Scalability and deployment challenges, Security and privacy concerns in digital twins, Interoperability and standardization, Roadmap for future research and development	
Text Books	
- Ranjan Ganguli, Sandipon Adhikari, Souvik Chakraborty, Mritika Ganguli, Digital Twin- A dynamic system and computing perspective, CRS Press - Khaled, N., Pattel, B., & Siddiqui, A. (2020). <i>Digital twin development and deployment on the cloud: developing cloud-friendly dynamic models using Simulink®/Simscape™ and Amazon AWS</i>. Academic Press. - Farsi, Maryam, et al., eds. "Digital twin technologies and smart cities." (2020). - Chapra, Steven C., and Raymond P. Canale. <i>Numerical methods for engineers</i>. Vol. 1221. New York: Mcgraw-hill, 2011. - Yang, W. Y., Cao, W., Kim, J., Park, K. W., Park, H. H., Joung, J., ... & Im, T. (2020). <i>Applied numerical methods using MATLAB</i>. John Wiley & Sons. - Strang, Gilbert. <i>Computational science and engineering</i>. Vol. 791. Wellesley, MA: Wellesley-Cambridge Press, 2007. - Karnopp, Dean C., Donald L. Margolis, and Ronald C. Rosenberg. <i>System dynamics: modeling, simulation, and control of mechatronic systems</i>. John Wiley & Sons, 2012. - Barber, David. <i>Bayesian reasoning and machine learning</i>. Cambridge University Press, 2012. - Grewal, Mohinder S., and Angus P. Andrews. <i>Kalman filtering: Theory and Practice with MATLAB</i>. John Wiley & Sons, 2014.	
Reference Books	
- Smith, Ralph C. <i>Uncertainty quantification: theory, implementation, and applications</i>. Society for Industrial and Applied Mathematics, 2024. - Peherstorfer, Benjamin, Karen Willcox, and Max Gunzburger. "Survey of multifidelity methods in uncertainty propagation, inference, and optimization." <i>Siam Review</i> 60.3 (2018): 550-591. - Karniadakis, George Em, et al. "Physics-informed machine learning." <i>Nature Reviews Physics</i> 3.6 (2021): 422-440. - Physics-Informed Neural Networks" (PINNs) – M. Raissi, P. Perdikaris, G. Karniadakis (papers & codes) "Deep Learning" – Ian Goodfellow, Yoshua Bengio, Aaron Courville - Tao, Fei, et al. "Digital twin-driven product design framework." <i>International Journal of Production Research</i> 57.12 (2019): 3935-3953.	

PGC-602 : Personality Development and Communication skills

Course Code	PGC-602	
Course Name	Audit Course	
L – T – P - C	2 – 0- 0 – 0	
Offered as (Compulsory / Elective):	Compulsory	
Offered in (SPRING / AUTUMN)	SPRING	

Offered by (Name of Department/ Centre)	PGC/All Departments DIAT
Unit I: English for Research Paper Writing Unit II: Disaster Management Unit II: Sanskrit for Technical Knowledge Unit IV: Value Education Unit V: Constitution of India Unit VI: Pedagogy Studies Unit VII: Stress Management by Yoga Unit VIII: Personality Development through Life Enlightenment Skills	

The following listed MOOC/NPTEL courses are found suitable by the Department and can be taken as an elective by the students. However, student may choose other MOOC/NPTEL courses as found relevant to their curriculum with the concurrence of the Programme co-ordinator.

Sl. No.	Course
1	Data Structures and Algorithms Design
2	Advanced Distributed Systems
3	Distributed Optimization and Machine Learning
4	Introduction to Machine Learning
5	Reinforcement Learning
6	Deep Learning for Computer Vision
7	Parameterized Algorithms
8	Applied Accelerated Artificial Intelligence
9	Social Network Analysis
10	The Joy of Computing using Python
11	Deep Learning - IIT Ropar
12	Stochastic Approximation: Theory and Applications
13	Computational Complexity
14	Cyber Security and Privacy
15	Privacy and Security in Online Social Media
16	Responsible & Safe AI Systems
17	Practical Cyber Security for Cyber Security Practitioners
18	Randomized Methods in Complexity
19	Computational Arithmetic - Geometry for Algebraic Curves
20	Secure Computation: Part II
21	Linear Algebra Through Geometry
22	Applied Linear Algebra for Signal Processing, Data Analytics and Machine Learning
23	Multi-Core Computer Architecture
24	Design & Implementation of Human-Computer Interfaces

25	Mathematical Foundations for Machine Learning
26	Statistical Learning for Reliability Analysis
27	Problem Solving through Programming in C
28	Ethical Hacking
29	Programming in Modern C++
30	Introduction to Industry 4.0 and Industrial Internet of Things
31	Introduction to Internet of Things
32	Introduction to Algorithms and Analysis
33	Algorithmic Game Theory
34	Approximation Algorithm
35	Real-Time Systems
36	Second Level Algorithms
37	Artificial Intelligence: Concepts and Techniques
38	Introduction to Large Language Models (LLMs)
39	Pattern Recognition and Application
40	Geographic Information System
41	Application of Forecasting, Regression and Time Series Models
42	Approximate Reasoning using Fuzzy Set Theory
43	Real Analysis II
44	Mathematical Methods and its Applications
45	Essential Mathematics for Machine Learning
46	Introduction to Fuzzy Set Theory, Arithmetic and Logic
47	Introduction to Methods of Applied Mathematics
48	Matrix Computation and its Applications
49	Computational Commutative Algebra
50	Excelling with Mathematical Modeling
51	Foundations of R Software (In Hindi Language)
52	Geometry of Curves and Surfaces
53	A Basic Course in Number Theory
54	Ordinary Differential Equations
55	A Primer to Mathematical Optimization
56	Category Theory
57	Introduction to Algebraic Geometry
58	Partial Differential Equations - IITB
59	An introduction to Point-Set-Topology Part - II
60	Galois Theory

61	Linear Algebra
62	An Introduction to Smooth Manifolds
63	Introductory Course in Real Analysis
64	Rings and Modules

Department Applied Physics

ABOUT Department of Applied Physics

The Department came into existence as Faculty of Applied Physics in 1952 and was renamed as Department of Applied Physics in 1979. We offer two M. Tech. Programmes namely, Laser & Electro-Optics and Sensors Technology. Also, we offer M.Sc. in Applied Physics (Photonics) and M.Sc. (Tech.) in Photonics.

We have a very strong Ph.D. Programme in Photonics, Lasers, Sensors, Advanced Functional Materials for Sensors, Photonics, and interdisciplinary applications in fields of healthcare, defense, and communication. We aim to train students for their career in academia as well as industry in the frontier areas of Science & Technology.

All our Masters and Ph.D. Programmes are a balance of fundamental science and advanced technology helping them to pursue career opportunities in Academia, Research & Industry.

Institute Vision

To be a Center of Excellence of international repute for Education, Training and research in Advanced Technologies with a view to strengthen national security and self-reliance.

Institute Mission

To evolve as an Innovative Unique Research University to develop indigenous contemporary Defence related technologies in Navigation Systems, Wireless Sensors, Efficient Propulsion Systems, and Weapon Systems for DRDO and Defence Services, provide technological solutions to the Services optimize combat battlefield effectiveness and above all produce qualified quality manpower which can truly become an instrument for building a strong indigenous technology base in the context of creating a performing Defence Industrial Base in India.

Department Vision

To be a Centre of Excellence of international repute for education, training and research in Advanced Sensor Technology, Photonics and Laser & Electro-optics with a view to strengthen National Security and Self Reliance.

Department Mission

- To impart higher education and training in various fields of Science and Technology having a bearing on the defence requirement in general and advanced Sensors, Photonics and Laser & Electro-optics in particular for the officers of the Ministry of Defence, Armed Forces, Public Sector Undertakings, Private Sectors, Industries, other related Organizations and general public.
- To carry out Research, Design and Development activities with a view to maintain adequate standards required for the above
- To strive for continuous learning, innovation, entrepreneurship and quality research culture amongst the student community through effective government industry and academia collaboration
- To encourage ethics, teamwork and technological leadership skills amongst students to solve complex engineering research problems collaboratively by imparting a strong theoretical foundation complemented with extensive practical training.
- To carry out multidisciplinary collaborative research in the frontier areas of science and technology.

M. Tech. in Sensor Technology/Laser and Electro-optics

Introduction: Sensors is one area of science and technology which has witnessed a paradigm shift from conventional bulky components to extremely miniaturized and smart devices. The technological advancements in the area of Electronics, Electrical engineering, along with the advancements in basic sciences in the areas of, nanotechnology, biotechnology and photonics have been responsible for this concomitant growth in the development of current sensors. An interdisciplinary approach that will involve materials engineering, electronics and electrical engineering along with a flavor of chemical engineering and bio-engineering, is now required to understand such sensors. The objective is to make them faster, smaller, smarter and more selective favor. This domain has, hence, seen a large number of Industries, Institutes and small entrepreneur companies coming up in recent times. The program intends to educate and train bright fresh students in the field of sensor technology to carry out challenging responsibilities in their future careers, and meet the current challenges and foster the opportunities which the globe has to offer. This is an interdisciplinary course concerning broadly Electronics, Instrumentation, Sensors, Optics, Electromagnetism, Nanotechnology and Advanced Materials.

One of the greatest scientific discoveries of the twentieth century that has led to technological advancement touching all aspects of human life is the LASER. Applications of lasers range from medical applications, communications, and industrial applications to military applications. An understanding of laser technology is essential for an engineer working in many of the present-day cutting-edge technologies. The aim of this program is to train the students in the field of lasers, fiber optics, electro-optics, and photonics that would enable them to meet the challenges in this rapidly developing field.

Eligibility: To join this course the candidate should possess Masters in science degree or equivalent in Physics, Applied Physics, Optics, Electronic Science, Photonics, Material science, Instrumentation Science OR 4-year BS/B. E./ B. Tech (all disciplines) as per the new Education Policy.

Organization: The program curriculum has been designed considering the Sensor Technology requirements of Industry and Defence Research and Development. It is designed and reviewed by a panel of experts from Academia, DRDO labs, IDS, R&D Industry, and Alumni. The course work includes Core and Elective courses related to the Sensor Technology domain.

Each subject of 3 credits is delivered by subject experts over the duration of 16 weeks approximately. It consists of 3 hrs. of classroom interaction per week. The evaluations follow a continuous assessment process that includes – 2 intermediate evaluation exams (20 Marks each), an internal assessment (10 Marks), and a final examination (50 Marks). The separate lab course focuses on practical exposure to the Sensor Technology and Laser and Electro-optic courses in the form of mini-projects and lab assignments and evaluated as per new PGC guidelines. The 3rd and 4th semesters have a major component of M.Tech. project dissertation of 20 credits each, where the students work under close supervision and guidance of their project guide. The students present their work at the end of 3rd and 4th semester. The M.Tech. thesis is submitted and evaluated by the panel of expert external examiners at the end of the 4th semester.

For 2-year M.Tech.: The M.Tech. Programmes will comprise of course work in the first year and research work in the second year. However, the students shall be allowed to opt for (i) only course work in the third and fourth semester or (ii) course work in the third semester and research in the fourth semester or (iii) only research in the third and fourth semester subject to meeting the credit requirements. For I-year M. Tech, Students entering I-year PG after a 4-year UG Programme with hons. with research and NEP in the same discipline can choose to do (i) only coursework or (ii) research or (iii) coursework and research meeting the credit requirements of at least 40 credits in a year. For a 2-year M. Tech, students may exit at the end of first year with an additional 3 credits course (CSE allied). Such students should be awarded the degrees as per the current NEP norms (M. Voc{Engg}) exiting at level 6.5 for M. Tech. enrolled students.

Program Educational Objectives (PEOs)

- PEO1** The M. Tech. in Sensor Technology/Lasers & Electro-Optics Programme aims at developing skilled human resources in the field of sensor development, embedded sensors system designing, sensor network, artificial intelligence, machine learning in Sensor Technology and Understanding of applied optics, physics and engineering of laser technology, fiber optics, semiconductor photonic devices, high power laser systems and its various applications, catering to the emerging multidisciplinary problems faced by defence industry and society.

- PEO2** With a focus on the DRDO requirements, the students will be trained to use their knowledge for the benefit of society and made aware of their social duty. This will enable them to pursue career in research, academics, and industry.
- PEO3** At the end of the Programme the officer or student should be able to undertake state of the art R&D in Sensor Systems/ Lasers and Electro-Optic systems (in academia / industry) and competitively work towards the development of the latest technology in line with national Programmes.

Program Outcomes (PO)

- PO1 Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- PO2 Problem Analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.
- PO3 Design/Development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- PO4 Conduct Investigations of Complex Problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions for complex problems.
- PO5 Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and Modeling to complex engineering activities with an understanding of the limitations.
- PO6 The Engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

Programme Specific Outcomes (PSO)

PSO1	The M. Tech. Sensor Technology/Lasers and Electro-Optics aims at developing a skilled knowledgeable human task -force in the field of Sensor Technology/Lasers and Electro-Optics catering to Defence Research and Development Organization & Tri – services (Army, Navy & Air force), Coast Guard, DGQA, DQA, Defence Public Sector units and civilians. After completing M. Tech. course, the students develop an ability

	to carry out independent research in the various areas of sensor technology and Optical Devices.
PSO2	The dissertation work of the MTech students leads to publications/Patents/conference presentations which trains them in technical presentation, documentation and report writing.
PSO3	The M. Tech. Sensor Technology /Lasers and Electro-Optics course aims at the development of human resources of high caliber in the field of sensor development, sensor systems, Machine learning, embedded system design. Most of the courses focus on employability/ entrepreneurship/ skill development/research aptitude in respective domains and provide solutions for the benefit of society.

MTech (Sensor Technology) Program Structure:

PSC: Program Specific Core PSL: Program Specific Lab PE: Professional Elective

SEMESTER I

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-1	AP 601	Fundamentals of Sensors	3	0	3
2	PSC-2	AP 602	Technology & Packaging of MEMS	3	0	3
3	PSC-3	AM 609	Data Science: Tools and Techniques	3	0	3
4	PSC-4	EE 620	System on Chip and Embedded Systems	3	0	3
5	PE-I	Elective I	Elective – I	3	0	3
6	PSL-I	AP 603L	Sensor Lab-I	0	6	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total	17	3	20

SEMESTER II

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	

1	PSC-5	AP 604	Sensor Systems	3	0	3
2	PSC-6	AM 623	Machine Learning	3	0	3
3	PE-II	Elective II	Elective – II	3	0	3
4	PE-III	Elective III	Elective – III	3	0	3
5	PE-IV	Elective IV	Elective – IV	3	0	3
6	PSL-II	AP 605L	Sensor Lab II	0	6	3
7	PGC	PGC-602	Communication Skills & Personality Development	2	0	2
			Total	17	3	20

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP-651	M.Tech. Dissertation and Seminar Phase-I	40		20
		Total	40		20

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP-652	M.Tech. Dissertation and Seminar Phase-II	40		20
		Total	40		20

List of Electives/Open Electives (Applicable for Sem - I):

Sr. No.	Course Code	Course
1.	AP 612	Fundamentals of Lasers
2.	AP 613	Semiconductor Photonic Devices
3.		MOOC Course

S.No.	Course Code	Course
1.	AP 616	Laser Applications
2.	AP 617	Computational Photonics

3.	AP 619	THz Device and Applications
4.	AP 620	Nanophotonics
5.	AP 621	Fiber Optic Devices and Systems
6.	AP 622	Free Space Optical Communication
7.		MOOC Course
8.		Open Elective
	The electives and other Core Courses offered in the 2nd semester by the other departments may be opted by the students on consultation with the course OIC/Department.	
	Maximum of 6 Credits can be opted by students as Professional Electives from the list of Online Courses on NPTEL/SWAYAM which are aligned to Applied Physics Domain with during Semester II.	

CORE Courses-Semester I		
Subject Code	AP 601	
Subject Title	Fundamentals of Sensors	
Credit	03	
Teaching Scheme	Lectures: 03 hours/week	
Evaluation Pattern	1. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 2. One Final Evaluation at the End of the Term 50 Marks 3. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks	
Total Marks	100 Marks	
Pre-requisite	Signal and their representation (Fourier and Laplace Transform), Electrical parameter measurement and techniques	
About the Course	This course provides an in-depth understanding of the fundamental principles and technologies involved in measurement and instrumentation. It covers the classification and characteristics of transducers, representation of signals, principles of electrical measurement systems, and the dynamics of instrument behavior. Emphasis is laid on both theoretical understanding and practical application of passive electrical transducers and signal processing techniques used in engineering measurements. The course lays the foundation for advanced instrumentation systems, control, and automation for sensors.	
Course Objectives	- To introduce the fundamentals of transducers and instrumentation systems. - To model the dynamic response of measurement systems. - To provide hands-on exposure to interfacing sensors with basic DAQ platforms. - To differentiate between passive and active sensor types and their applications.	
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create	
CO Title	Bloom's Level and Descriptor	
	CO1:	Explain the types, characteristics, and classifications of transducers. Understand (Level 2)
	CO2:	Analyze the dynamic response of instrumentation systems using system models. Analyze (Level 4)
	CO3:	Implement sensor interfacing and understand data acquisition fundamentals. Apply (Level 3)

	CO4:	Differentiate and apply passive sensor technologies in practical setups.	Apply, Analyze (Level 3, Level4)						
	CO5:	Demonstrate understanding and use of active sensor technologies.	Apply (Level 4)						
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics								
		PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
	CO1	3	2				3	1	2
	CO2	3	3	2			3	1	2
	CO3	3	2	2	3	3	3	1	2
	CO4	3	3	3	2	3	3	1	2
	CO5	3	2	2	2	2	3	1	2
Syllabus Details:							Text/Ref. Books	Hrs	CO(s)
Unit 1	Measurement, Instruments, and Instrumentation: Definitions and types of instruments, Classification of transducers, Performance characteristics: accuracy, precision, sensitivity, resolution, etc., Errors in measurement: systematic, random, and environmental, Calibration methods and standards					Text Book-1, Ch- 1	06 Hours	CO1	
Unit 2	Dynamics of Instrument Systems: Generalized performance of systems, Zeroth, first, and second-order systems: time response and system parameters, System modeling: block diagram representation, Electrical analogs of mechanical systems, Dynamic compensation and filtering basics					Text Text Book-1, Ch- 4, Text Book-2 Ch-3	08 Hours	CO2	
Unit 3	Sensor Interfacing and Data Acquisition Basic microcontroller interfaces (Arduino, PIC): Analog to digital conversion: resolution, sampling rate, Nyquist criterion and aliasing, Use of multiplexers, sample-and-hold circuits, introduction to DAQ systems and simple data logging					Text Book-2 Ch-14, 16	10 Hours	CO3	
Unit 4	Passive Sensors: Resistive sensors: thermistors, RTDs, strain gauges, Inductive sensors: LVDT, variable reluctance, Capacitive sensors: displacement, pressure, humidity					Text Book 1 Ch 6, Text Book 3 Ch 2	8 Hours	CO4	
Unit 5	Active Sensors: Thermoelectric transducers: thermocouples, Piezoelectric sensors: force, vibration, ultrasound applications, Magnetic sensors: Hall effect, magneto-resistive sensors					Text Book 1 Ch 7, Text Book 3 Ch 4	8 Hours	CO5	
Text Books (Must Know), Ref. as (T-x) in the Syllabus	1. D V S Murty, ‘Transducers and Instrumentation’, PHI Learning Pvt Ltd. 2013 2. ‘Instrumentation Devices and Systems’, C S Rangan, G R Sarma, V S V Mani Mc Graw Hill Education (India) Private Limited. 2013 3. ‘Sensors and Transducers’, D Patranabhis, PHI Learning Pvt Ltd. 2013.								
Reference Book (Should Know) Ref. as (R-x) in the Syllabus	1. Handbook of Modern Sensors: physics, designs and applications by Jacob Fraden, Springer 2010. 2. Sensor Technology Handbook by John S Wilson, Elsevier, 2005. 3. Ramon Pallas-Areny and John G Webster, Sensors and Signal Conditioning, Wiley India Pvt. Ltd., 2nd ed., 2012.								

CORE Courses-Semester I																																												
Subject Code	AP 602																																											
Subject Title	Technology and Packaging of MEMS																																											
Credit	03																																											
Teaching Scheme	Lectures: 03 hours/week																																											
Evaluation Pattern	1. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 2. One Final Evaluation at the End of the Term 50 Marks 3. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks																																											
Total Marks	100 Marks																																											
Pre-requisite	Knowledge of Basic Electronics																																											
About the Course	The purpose of this course is to get an understanding of the Micro and nano systems that are increasingly being used in various mechanical, electrical, materials and electronic domains. It has been planned to cover the science and engineering of these Microsystems fabrication in this course. The course will start with the introduction to micro and nano systems and the current status of development and applications in this field. The course covers design and fabrication of various components of micro systems by various methods, VLSI technology in details. After that the course delves into the synthesis of nano materials and systems by different routes and the applications of the same. In the end different case studies are conducted in order to give a flavor of actual microsystem design and development to students.																																											
Course Objectives	This course will help sensor technology students to understand the real-life Microsystems fabrication processes since both the fields utilize many such Microsystems.																																											
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create																																											
CO Title		Bloom’s Level and Descriptor																																										
	CO1:	Students to understand the technologies involved in MEMS fabrication, their advantages and limitations Understand (Level 2)																																										
	CO2:	Students to understand the technologies involved in MEMS packaging, their advantages and limitations Understand (Level 2)																																										
	CO3:	Students to be able to grasp and analyze the working principles in micro sensors and actuators Analyze (Level 4)																																										
	CO4:	Students to be able to understand the differences and similarities between VLSI and MEMS technologies Apply (Level 3)																																										
	CO5:	Students to become capable of conceptualizing the design of a microsystem. Create (Level 6)																																										
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics <table><tr><td></td><td>PO1</td><td>PO2</td><td>PO3</td><td>PSO1</td><td>PSO2</td><td>PSO3</td></tr><tr><td>CO1</td><td>3</td><td>2</td><td>1</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO2</td><td>3</td><td>1</td><td>2</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO3</td><td>1</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO4</td><td>1</td><td>3</td><td>2</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO5</td><td>1</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td></tr></table>			PO1	PO2	PO3	PSO1	PSO2	PSO3	CO1	3	2	1	3	1	2	CO2	3	1	2	3	1	2	CO3	1	2	3	3	1	2	CO4	1	3	2	3	1	2	CO5	1	2	3	3	1	2
	PO1	PO2	PO3	PSO1	PSO2	PSO3																																						
CO1	3	2	1	3	1	2																																						
CO2	3	1	2	3	1	2																																						
CO3	1	2	3	3	1	2																																						
CO4	1	3	2	3	1	2																																						
CO5	1	2	3	3	1	2																																						

Syllabus Details:		Text/Ref. Books	Hrs	CO(s)
Unit 1	Benefits of micro systems, concept of micro machines/ micro systems, Scaling Laws in Miniaturization: Introduction to scaling, geometric scaling, scaling in rigid body dynamics, scaling in electrostatic forces, scaling in electromagnetic Electricity, scaling in fluid mechanics, Scaling in Heat Transfer	T1	8	1
Unit 2	Engineering, Science & Materials for Microsystems: Atomic structure, Crystal Structures, Bonding in materials, Ionization, Doping in Semiconductors, Diffusion Process, Plasma Physics, Electrochemistry, Silicon as a substrate material for MEMS, Compounds of silicon, Si Piezo resistors, other Piezo electric materials, GaAs, Polymer, Materials used in packaging	T1	6	2
Unit 3	Fabrication of Microsystems: Introduction, Photolithography, Ion Implantation, Diffusion, Oxidation, Chemical & Physical Vapor deposition, Epitaxial growth of films, Chemical etching, Plasma etching. Bulk and Surface Micromachining, LIGA Process	T1, T2	12	3
Unit 4	Working principles of microsystems: Microsensors: Acoustics wave sensors, Biomedical & Bio sensors, Chemical Sensors, Optical Sensors, Pressure Sensors, Thermal Sensors, MEMS with Micro actuators: Microgripper, Micromotors, Micro valves, Micro pumps, Micro accelerometer, Microfluidics	T1, T3	8	4
Unit 5	Microsystem packaging: Packaging in VLSI and microsystems, Levels in microsystem packaging, Interfaces in Microsystem packaging, Assembly of Microsystems. Essential packaging technologies, 3-d Packaging, Multi User MEMS Program (MUMPs)	T1, T3	8	5
Text Books (Must Know), Ref. as (T-x) in the Syllabus	1] Tai-Ran Hsu, 'MEMS & Microsystem, Design and manufacture', McGraw Hill, 2012 2] Mark J Jackson, Micro and Nano-manufacturing, Springer; First Edition, (2006). 3] Zheng Cui, Micro-nanofabrication: Technologies and Applications, Springer, First Edition (2006), ISBN-10:3540289224			
Reference Book (Should Know) Ref. as (R-x) in the Syllabus	1] Physics of Semiconductor Devices by S.M. Sze, Wiley Publications(2006) 2] Streetman, Ben, and Sanjay Banerjee. Solid state electronic devices. Pearson Higher Ed, 2015. 3] R. Kassing, P. Petkov, W. Kulish, C. Popov., Functional Properties of Nanostructured Materials. Springer (ISBN: 978-1-4020-4595-0 (Print)			

Lab Courses-Semester I	
Subject Code	AP 603L
Subject Title	Sensor Technology Lab -1
Credit	03
Teaching Scheme	Laboratory experiment: 06 hours/week
Evaluation Pattern	1. Continuous Evaluations: Experiments, Lab Records and Vive-voce 40 Marks (20 + 10 + 10) 2. Mini-Project and Term Work Evaluations: 10 Marks 3. One Final Evaluation at the End of the Term 50 Marks
Total Marks	100 Marks
Pre-requisite	None

About the Course	This lab course provides hands-on experience with a wide range of modern sensors and instrumentation systems, spanning automotive, optical, temperature, and pressure sensors. The course emphasizes real-time data acquisition and processing using tools like Arduino and introduces students to hands-on experiments on optical sensors, including optical fiber technologies.																																																																					
Course Objectives	1. To enable students to understand the operation and interfacing of various sensors including automotive, temperature, pressure, vibration, and optical sensors. 2. To provide practical exposure to sensor data acquisition and processing using platforms like Arduino. 3. To conduct experiments that demonstrate the material properties influencing sensor behaviour using methods like the Hall effect. 4. To study advanced optical sensing techniques including fiber Bragg gratings, interferometry, and fiber splicing.																																																																					
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create																																																																					
CO Title								Bloom's Level and Descriptor																																																														
	CO1:	Interpret the concepts of basic physics behind several sensors					Understand (Level 2)																																																															
	CO2:	Analyze optical electrical and thermal properties					Analyze (Level 4)																																																															
	CO3:	Examine situations where the sensors based on the above properties can be used					Apply (Level 3)																																																															
	CO4:	Illustrate implementation of sensor system using Arduino					Apply, Analyze (Level 3, Level4)																																																															
	CO5:	Summarize different applications where sensor system can be used					Evaluate (Level 5)																																																															
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics <table><tr><td></td><td>PO1</td><td>PO2</td><td>PO3</td><td>PO4</td><td>PO5</td><td>PO6</td><td>PSO1</td><td>PSO2</td><td>PSO3</td></tr><tr><td>CO1</td><td>1</td><td>2</td><td></td><td></td><td></td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO2</td><td>1</td><td>3</td><td>2</td><td></td><td></td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO3</td><td>1</td><td>2</td><td>2</td><td>1</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO4</td><td>1</td><td>3</td><td>3</td><td>1</td><td>3</td><td>2</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO5</td><td>1</td><td>2</td><td>2</td><td>1</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td></tr></table>											PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3	CO1	1	2				3	3	1	2	CO2	1	3	2			3	3	1	2	CO3	1	2	2	1	2	3	3	1	2	CO4	1	3	3	1	3	2	3	1	2	CO5	1	2	2	1	2	3	3	1	2
	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3																																																													
CO1	1	2				3	3	1	2																																																													
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CO3	1	2	2	1	2	3	3	1	2																																																													
CO4	1	3	3	1	3	2	3	1	2																																																													
CO5	1	2	2	1	2	3	3	1	2																																																													
Syllabus Details:								Hrs	CO(s)																																																													
	<u>List of Experiments:</u>																																																																					
1.	To Study Hall Effect and to determine Hall voltage, Hall coefficient and type of majority carriers and determine Hall Angle							6	CO1																																																													
2.	Estimate the Verdet's constant through Faraday Effect for a given crystal							6	CO1																																																													
3.	Determination of various optical parameters of Optical Fiber							6	CO2																																																													
4.	Temperature Sensing through Fiber optics							6	CO2																																																													
5.	Determine the Micro and Macro-bending Loss & Application in Sensing							6	CO2																																																													

6.	Determine the wavelength of He-Ne laser using Michelson Interferometer	6	CO2
7.	To interface LED with Arduino and determine the modulation characteristics	6	CO3
8.	Program LED to Blink, use for traffic Light, vary the intensity of LED using PWM, Interface Pot + LED with Arduino	6	CO3
9.	Understand the working of touch sensor and Interface with Arduino and use it for some application	6	CO1 CO4
10.	Interface LCD with Arduino and use it to display some sensor output	6	CO3
11.	Interface different sensors individually and simultaneously with Arduino like LM 35, DHT 22, Ultrasonic Sensor and understand the challenges in interfacing different types of sensors simultaneously	6	CO4, CO5
12.	Interface servo motor with Arduino and use it along with some sensor for some application	6	CO5
13.	Use soil moisture sensor along with some other sensors and actuators and make automatic plant watering set-up.	6	CO5
14.	Interface Joystick with Arduino and use it for positioning and displaying the position	6	CO4
15.	Implement RADAR system using Arduino.	6	CO4
16.	Mini Project	6	CO1- CO5

CORE Courses-Semester II	
Subject Code	AP 604
Subject Title	Sensor Systems
Credit	03
Teaching Scheme	Lectures: 03 hours/week
Evaluation Pattern	1. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 2. One Final Evaluation at the End of the Term 50 Marks 3. Assignments/Seminar Evaluations: 10 Marks
Total Marks	100 Marks
Pre-requisite	None
About the Course	This course provides in-depth exposure to advanced sensing technologies and their integration into real-world systems. It covers a wide range of sensors including vibration, pressure, radiation, position, optical, chemical, and biosensors. The course aims to develop analytical and practical skills needed to evaluate, choose, and implement appropriate sensors for multidisciplinary applications in industrial automation, biomedical instrumentation, robotics, and structural health monitoring.
Course Objectives	- Understand the working principles and design considerations of advanced physical, chemical, and optical sensors. - Analyze the dynamic behavior and interfacing needs of different sensor systems. - Evaluate the suitability of various sensors for specific real-world engineering applications. - Gain hands-on skills in sensor integration and signal processing. - Be equipped to propose innovative sensor-based solutions for emerging challenges in science and engineering.
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5

		Evaluate; Level-6 Create									
CO Title	Description							Bloom's Level and Descriptor			
	CO1:										
	CO2:	Analyze vibration, pressure, force, and torque sensor systems and their performance metrics.							Analyze		
	CO3:	Evaluate radiation sensors for medical, industrial, and scientific applications.							Evaluate		
	CO4:	Compare different techniques for sensing position, displacement, velocity, and acceleration.							Analyze/Evaluate		
	CO5:	Distinguish and interpret chemical and biosensor types and their implementation challenges.							Understand/Evaluate		
Summary of the Course Outcome		Course Outcome and Program Outcome Evaluation Metrics									
			PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
		CO1	3	3	2	2	2	—	3	1	2
		CO2	3	2	2	3	2	2	3	1	2
		CO3	3	3	2	3	2	—	3	1	2
		CO4	3	2	2	2	3	2	3	1	2
		CO5	3	2	3	3	3	1	3	1	2
Syllabus Details:											
		Text/Ref. Books							Hrs	CO(s)	
Unit 1	Vibration, Pressure, Force, and Torque Sensors - Vibration sensors: Piezoelectric, MEMS accelerometers, eddy current probes, laser vibrometers - Pressure sensors: Piezoresistive, capacitive, optical, resonant, vacuum sensors (Pirani, ionization) - Force sensors: Strain gauge-based load cells, piezoelectric force sensors - Torque measurement: Optical, magnetoelastic, and strain-gauge based torque sensors - Calibration, error sources, and compensation techniques - Magneto Sensors - Image Sensing and processing							T1, T2, T3		8	1
Unit 2	Radiation Sensors - Infrared (IR) sensors: Thermopiles, bolometers, and pyroelectric detectors - Ultraviolet (UV) sensors: Photodiodes, photomultiplier tubes - Gamma and X-ray sensors: Scintillation detectors, semiconductor detectors (Ge, CdTe) - Neutron detectors: Helium-3, BF₃ tubes - Applications in NDT, imaging, environmental, and safety systems							T1		6	2
Unit 3	Position, Displacement, Velocity, and Acceleration Sensors							T1, T2		10	3

	- Position and displacement: LVDT, RVDT, capacitive and inductive sensors, optical encoders - Velocity measurement: Tachometers, Doppler sensors using sound/light - Acceleration sensors: MEMS accelerometers, piezoelectric types - Angular velocity/gyroscopes: MEMS, fiber optic gyros (FOG), ring laser gyros (RLG) - Inertial measurement units (IMU) and data fusion basics			
Unit 4	Chemical and Biosensors - Chemical sensors: Potentiometric, amperometric, conductometric sensors - Gas sensors: MOS, NDIR, electrochemical, catalytic bead sensors - Biosensors: Enzyme-based, immunosensors, DNA biosensors - Microfluidics and lab-on-chip systems - Applications: Environmental monitoring, medical diagnostics, industrial process control		9	4
Unit 5	Optical and Photonic Sensors - Basics of photonics and light-matter interaction - Fiber optic sensors: Intensity, FBG, interferometric (Fabry–Perot, Mach–Zehnder) - Photodiodes, phototransistors, and photomultiplier tubes - Laser sensors: Triangulation-based distance sensors, LIDAR basics - Applications in structural health monitoring, smart infrastructure, robotics - Cooled and Uncooled Sensors - Electro-Optic Sensors - Quantum Sensors	T1	9	5
Text Books (Must Know), Ref. as (T-x) in the Syllabus	1. ‘Sensors and Transducers’, D. Patranabis, PHI Learning, 2013. 2. ‘Transducers and Instrumentation’, D V S Murty, PHI Learning, 2013. 3. ‘Instrumentations Devices, & Systems’, C S Rangan, G R Sarma, V S V Mani, McGraw, Hill Education Pvt Ltd., 2013.			
Reference Book (Should Know) Ref. as (R-x) in the	1. ‘Optical Sensors: Basics and Applications’, Jiri Tuma, CRC Press, 2013. 2. ‘Chemical Sensors and Biosensors: Fundamentals and Applications’, Florinel-Gabriel Banica, Wiley, 2013			

Syllabus	

Lab Courses-Semester II		
Subject Code	AP 605L	
Subject Title	Sensor Technology Lab -II	
Credit	03	
Teaching Scheme	Laboratory: 06 hours/week	
Evaluation Pattern	1. Continuous Evaluations: Experiments, Lab Records and Vive-voce 40 Marks (20 + 10 + 10) 2. Mini-Project and Term Work Evaluations: 10 Marks 4. One Final Evaluation at the End of the Term 50 Marks	
Total Marks	100 Marks	
Pre-requisite	None	
About the Course	This laboratory course provides hands-on training in integrating and operating sensor systems and embedded platforms for automation and control applications. The experiments cover a range of modern technologies including Raspberry Pi interfacing, sensor integration (e.g., PIR, touch, humidity, temperature), control components like relays and rotary encoders, as well as systems for data acquisition and control. The course further includes exposure to wireless sensor networks and flow measurement systems, making it highly relevant to real-world industrial and defense applications.	
Course Objectives	1. To introduce students to embedded systems and their interfacing using Raspberry Pi. 2. To develop practical skills in integrating various sensors and actuators for measurement and control. 3. To familiarize students with industrial automation components. 4. To provide exposure to wireless sensor networks and their applications. 5. To enable students to design and implement basic monitoring and control systems relevant to industrial and defence technologies.	
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create	
CO Title	Bloom's Level and Descriptor	
	CO1:	Interpret the basic concepts of microcomputer Understand (Level 2)
	CO2:	Analyze different types of microcomputers Analyze (Level 4)
	CO3:	Examine situations where they can be used Apply (Level 3)
	CO4:	Illustrate implementation of sensor system using Raspberry Pi Apply, Analyze (Level 3, Level4)
	CO5:	Summarize different applications of microcomputer in real life Evaluate (Level 5)

Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics									
		PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
	CO1	1	2				3	3	1	2
	CO2	1	3	2			3	3	1	2
	CO3	1	2	2	1	2	3	3	1	2
	CO4	1	3	3	1	3	2	3	1	2
	CO5	1	2	2	1	2	3	3	1	2
Syllabus Details:							Text/Ref. Books	Hrs	CO(s)	
<u>List of Experiments:</u>										
1.	LED blink and traffic light.							6	CO1	
2.	LED brightness control using PWM.							6	CO1	
3.	Touch Sensor interface to blink the LED.							6	CO1	
4.	Create counter using touch sensor.							6	CO2	
5.	Interface LCD display using I2C and display date and time.							6	CO2	
6.	Interface DHT11 sensor to display the output of LCD and log the data in real time.							6	CO2	
7.	Interface Ultrasonic sensor and display distance on LCD.							6	CO2	
8.	Interface servo motor using PWM.							6	CO2	
9.	Analog sensing with raspberry pi: Exploring potentiometer input using ADS1115 ADC module.							6	CO3	
10.	Interfacing of LM35 with raspberry pi and ADS1115 ADC module and plot the data in real time.							6	CO3	
11.	Pi joystick interface: Analog control exploration with ADS1115 ADC module.							6	CO3	
12.	Control servo motor using joystick.							6	CO4	
13.	Create radar system with help of servo motor, ultrasonic sensor and joystick.							6	CO4	
14.	Interfacing of soil moisture sensor with raspberry pi.							6	CO5	
15.	Mini Project							6	CO1-CO5	

MTech (Laser and Electro-optics) Program Structure:

PSC: Program Specific Core PSL: Program Specific Lab PE: Professional Elective

SEMESTER I

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-1	AP 611	Quantum Mechanics for Engineers	2	1	3
2	PSC-2	AP 612	Laser Technology	3	0	3
3	PSC-3	AP 613	Semiconductor Photonic Devices	3	0	3
4	PSC-4	AP 614	Optical Electronics	3	0	3
5	PE-I		Elective - I	3	0	3
6	PSL-I	AP 615L	Laser and Electro-optic Lab - I	0	6	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total	17	3	20

SEMESTER II

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-5	AP 616	Laser Applications	3	0	3
2	PSC-6	AP 617	Computational Photonics	1	2	3
3	PE-II	AP XXX	Elective – II	3	0	3
4	PE-III	AP XXX	Elective – III	3	0	3
5	PE-IV		Elective – IV	3	0	3
6	PSL-II	AP 618L	Laser and Electro-optic Lab - II	0	6	3
7	PGC	PGC-602	Communication Skills & Personality Development	2	0	2
			Total	17	3	20

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP-651	M.Tech. Dissertation and Seminar Phase-I	40		20
		Total	40		20

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP-652	M.Tech. Dissertation and Seminar Phase-II	40		20
		Total	40		20

List of Subjects (Applicable for Sem - II):

S.No.	Course Code	Course
1.	PGC-602	English for Research Paper Writing
2.		Disaster Management
3.		Sanskrit for Technical Knowledge
4.		Value Education
5.		Constitution of India
6.		Pedagogy Studies
7.		Stress Management by Yoga
8.		Personality Development through Life Enlightenment Skills

List of Electives/Open Electives (Applicable for Sem - I):

Sr. No.	Course Code	Course
1.	AM 609	Data Science: Tools and Techniques
2.	AP 602	Technology & Packaging of MEMS
3.		MOOC Course

List of Electives/Open Electives (Applicable for Sem - II):

S.No.	Course Code	Course
1.		MOOC Course
2.		Open Elective
3.	AP 619	THz Device and Applications
4.	AP 620	Nanophotonics
5.	AP 621	Fiber Optic Devices and Systems
6.	AP 622	Free Space Optical Communication
7.	AP 604	Sensor Systems
	The electives and other Core Courses offered in the 2 nd semester by the other departments may be opted by the students on consultation with the course OIC/Department.	
	Maximum of 6 Credits can be opted by students as Professional Electives from the list of Online Courses on NPTEL/SWAYAM which are aligned to Applied Physics Domain with during Semester II.	

CORE Courses-Semester I	
Subject Code	AP 611
Subject Title	Quantum Mechanics for Engineers
Credit	03
Teaching Scheme	Lectures: 03 hours/week
Evaluation Pattern	1. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 2. One Final Evaluation at the End of the Term 50 Marks 3. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks
Total Marks	100 Marks
Pre-requisite	None
About the Course	This course provides a foundational understanding of Quantum Mechanics, essential for students in physics and engineering disciplines working with atomic, molecular, and photonic systems. It introduces the mathematical formalism of quantum theory and its physical interpretations, enabling students to analyze simple quantum systems such as potential wells, harmonic oscillators, and one-electron atoms. Additionally, it covers quantum statistics and forms the basis for understanding lasers and modern quantum technologies
Course Objectives	By the end of this course, the students will be able to: • Understand the fundamental postulates of quantum mechanics and how they differ from classical physics. • Formulate and solve the Schrödinger equation for various potential problems in one and three dimensions. • Apply the formalism of quantum mechanics, including Hilbert spaces, operators, and Dirac notation. • Analyze atomic systems, such as the hydrogen atom, using appropriate mathematical tools. • Explore the principles of quantum statistics and their role in physical systems involving indistinguishable particles.

	Relate quantum mechanical principles to practical systems such as lasers, optical devices, and semiconductor physics.																																																								
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create																																																								
CO Title			Level	Descriptor																																																					
	CO1:	Explain core concepts of thermal radiation, Planck's postulates, and Schrödinger's equation.	2	Understand																																																					
	CO2:	Solve quantum systems such as potential wells and harmonic oscillators using analytical techniques.	3	Apply																																																					
	CO3:	Apply Dirac notation, operator algebra, and statistical interpretation in solving quantum mechanical problems.	4, 5	Apply/Analyze																																																					
	CO4:	Analyze hydrogen-like atoms and interpret eigenvalue problems in three-dimensional quantum systems.	4	Analyze																																																					
	CO5:	Explain and apply the principles of quantum statistics and their applications in quantum devices.	2, 3	Understand/Apply0020																																																					
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics																																																								
	<table><tr><td></td><td>PO1</td><td>PO2</td><td>PO3</td><td>PO4</td><td>PO5</td><td>PSO1</td><td>PSO2</td><td>PSO3</td></tr><tr><td>CO1</td><td>3</td><td>2</td><td>-</td><td>1</td><td></td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO2</td><td>3</td><td>3</td><td>2</td><td>2</td><td></td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO3</td><td>3</td><td>3</td><td>-</td><td>2</td><td></td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO4</td><td>3</td><td>3</td><td>-</td><td>2</td><td></td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO5</td><td>3</td><td>2</td><td>-</td><td>2</td><td>1</td><td>3</td><td>1</td><td>2</td></tr></table>					PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3	CO1	3	2	-	1		3	1	2	CO2	3	3	2	2		3	1	2	CO3	3	3	-	2		3	1	2	CO4	3	3	-	2		3	1	2	CO5	3	2	-	2	1	3	1
	PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3																																																	
CO1	3	2	-	1		3	1	2																																																	
CO2	3	3	2	2		3	1	2																																																	
CO3	3	3	-	2		3	1	2																																																	
CO4	3	3	-	2		3	1	2																																																	
CO5	3	2	-	2	1	3	1	2																																																	
Syllabus Details:																																																									
Unit 1	Introduction: Thermal radiation, Plank's postulates, The Schrödinger equation, Statistical interpretation, probability, normalization, momentum, the uncertainty principle		Text Book-1, Ch- 1 Text Book 2 Chapter 1	10 Hrs	CO1																																																				
Unit 2	Time Independent Schrödinger: stationary states, infinite square well, harmonic oscillator, free particle, delta function potential, finite square well		Text Book-2 Chapter 2	9 Hrs	CO2																																																				
Unit 3	Formalism: Hilbert's space, observables, eigen function of Hermitian Operator, statistical interpretation, Dirac notation		Book 1 Ch-2 Book 2 Ch-3	9 Hrs	CO3																																																				
Unit 4	One electron atom: solution of Schrödinger equation in 3D, eigen values, quantum numbers, and degeneracy, orbital angular		Text Book 1 CH-4	9 Hrs	CO4																																																				

Unit 5	Quantum statistics: indistinguishability and quantum statistics, quantum distribution functions, Boltzmann distribution as an approximation to quantum distributions, The Lasers, Density Matrix Calculation, Fermi-Golden Rule, susceptibility calculation for atom and cluster of atoms	Text Book 1 Ch-8 Reference Book 1	8 Hrs	CO5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. Zettili, Nouredine. "Quantum mechanics: concepts and applications." John Wiley and Sons, Ltd., Publishing 2nd Ed. (2009) 2. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing Limited			
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	1. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing 2. Beiser, Arthur. Concepts of modern physics. 2003.			

CORE Courses-Semester I	
Subject Code	AP 612
Subject Title	Laser Technology
Credit	03
Teaching Scheme	Lectures: 03 hours/week
Evaluation Pattern	1. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 2. One Final Evaluation at the End of the Term 50 Marks 3. Assignments/Seminars: 10 Marks
Total Marks	100 Marks
Pre-requisite	Basic Physics Knowledge
About the Course	This course provides an in-depth understanding of the fundamental principles and technologies involved in lasers. This course provides a comprehensive introduction to the fundamental principles and operation of lasers. It covers the physical concepts underlying laser action, including stimulated emission, population inversion, and optical feedback. The course also explores the various types of lasers, their design, characteristics.
Course Objectives	- Explain the physical principles of laser operation, including the quantum mechanics of light-matter interaction. - Understand the role of gain media, pumping mechanisms, and optical resonators in laser systems. - Analyze the behavior of laser beams, including coherence, mode structure, and beam propagation. - Compare different types of lasers (gas, solid-state, semiconductor, fiber laser and amplifiers) and their applications.

	Solve quantitative problems involving laser parameters such as output power, threshold conditions, and efficiency.								
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create								
CO Title						Bloom's Level and Descriptor			
	CO1:	Understand and explain the fundamental principles of laser physics, including stimulated emission, population inversion, and optical amplification.				Understand (Level 2)			
	CO2:	Analyze the operation of laser systems using rate equations and energy-level diagrams for different types of gain media				Apply (Level 3)			
	CO3:	Describe the components and function of optical resonators, and evaluate their role in mode selection and laser beam formation.				Analyze (Level 4)			
	CO4:	Apply concepts of Gaussian beam optics to describe laser beam propagation, focusing, divergence, and spot size.				Apply (Level 3)			
	CO5:	Solve quantitative problems related to laser threshold conditions, gain, power output, and efficiency.				Evaluate (Level 5)			
	CO6:	Create a laser system and perform basic laser experiments, including alignment, power measurement, and beam profiling, with proper safety precautions.				Apply (Level 6)			
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics								
		PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
	CO1	3	2	1			3	1	2
	CO2	2	3	1			3	1	2
	CO3	3	2	1			3	1	2
	CO4	3	2	1	1	1	3	1	2
	CO5	1	2	3	1	1	3	1	2
	CO6	1	1	1	1	3	3	1	2
Syllabus Details:					Text/Ref. Books	Hrs	CO(s)		
Unit 1	Light-matter interaction: Interaction of radiation with atomic systems, Einstein's coefficients, spontaneous emission, stimulated emission, Linewidth of the laser, line broadening, concepts of Q-switching and modelocking				T1, T2	6	1		
Unit 2	Lasers Oscillation: Threshold condition, Rate equation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output, Spectral distribution, Spatial distribution and polarisation, Hole burning, Properties of laser beam, Pumping techniques.				T1, T2	12	2		
Unit 3	Laser Resonators and Gaussian Beams: The Ray Matrix, Resonator Stability, Paraxial Wave Equation, Gaussian Beams, ABCD Law for Gaussian Beams, Gaussian Beam Modes, Hermite–Gaussian and Laguerre–Gaussian Beams, Resonators for He–Ne Lasers, Diffraction, Diffraction Theory of Resonators, Beam Quality, Resonators for High-Power Lasers.				T2, T3	10	3		

Unit 4	Laser Systems 1: Neodymium-Based Lasers, Titanium Sapphire Laser, He-Ne Laser, CO ₂ and Fiber Lasers & Amplifiers. Hands-On Experiments: Design Nd: YAG Laser, Fiber Laser & Amplifier (Students will design and assemble in a group)	T1, T2, T3	9	4
Unit 5	Laser Systems 2: Semiconductor Lasers, Optical Gain in Semiconductors, Quantum Well Lasers, Quantum Dot Laser, and Quantum Cascade Laser	T4	9	5
Text Books (Must Know), Ref. as (T-x) in the Syllabus	1. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007) 2. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998. 3. P. W. Milonni and J. H. Eberly, Lasers, Wiley Inter Science, 1988. 4. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).			
Reference Book (Should Know) Ref. as (R-x) in the Syllabus	1. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021). 2. Streetman, Ben, and Sanjay Banerjee. Solid state electronic devices. Pearson Higher Ed, 2015. 3. The W. Koechner, "Laser Fundamentals"			

CORE Courses-Semester I	
Subject Code	AP 613
Subject Title	Semiconductor Photonic Devices
Credit	03
Teaching Scheme	Lectures: 03 hours/week
Evaluation Pattern	4. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 5. One Final Evaluation at the End of the Term 50 Marks 6. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks
Total Marks	100 Marks
Pre-requisite	B.Sc. Physics or Engineering Physics Knowledge
About the Course	Semiconductor Photonic Devices is the basic to advanced level subject which provides fundamental knowledge of different semiconductor material and its application in the photonic devices from sources to detectors. The course will give a explanation about working principles of devices such as LEDs, lasers, Detector, Photonic integrated circuit etc. The course will start with the introduction to properties of semiconductors, band structures, optical electronics, solving of Maxwell's equations, wave equation in anisotropic media, Uniaxial and biaxial crystals, the determination of dielectric constant, tensor and the 'index ellipsoid'. The Fresnel's equation also explored for Reflection and Refraction of plane waves. Later, it also covers the concepts of polarisation of light through different optical components, like Polarisers, Quarter, Half, and Full waveplates, Beam splitters, wavelength filters, dichroic mirrors, Lenses, etc. It also deals with study of absorption and dispersion, Jones Calculus, Poincare sphere, with polarized and non-polarized lights. In unit 3, Electro-optical effects such as, Pockel and Kerr effects, Electro-optic modulators, switches, and scanners, E.O. effect in liquid crystals are discussed thoroughly and their applications in LCDs and SLMs. Furthermore, the acousto-optical effects, like, Strain waves in solids and liquids, the strain-optic tensor, theory of Raman-Nath and Bragg diffraction, small-angle and large-angle Bragg

	diffraction are explained with derivation. Acousto-optic devices, such as, modulators, deflectors, scanners, interconnections, acousto-optic tunable filters, are studied thoroughly.						
	Similarly, in Unit 5, the Magneto-optical effects, such as, Faraday effect, Gyrotropic permittivity, Kerr rotation, and Kerr ellipticity and its applications also been discussed. Finally, the current status of development and applications of this areas are covered.						
Course Objectives	This course is helping M. Tech. ‘Laser and Electro-optics’ students and similar branches to understand how the opto-electronic systems are working to fulfil the current needs of our society.						
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create						
CO Title				Level	Descriptor		
	CO1:	Understand the basics of Semiconductor Physics		1, 2	Remember; Understand		
	CO2:	Interpret all the optical properties and processes in semiconductors		2, 3	Understand; Apply		
	CO3:	Examine the working mechanism of different kinds of LEDs and LASERs		2, 3	Understand; Apply		
	CO4:	Illustrate the implementation of Modulation and Switching Devices		3, 4	Apply; Analyze		
	CO5:	Explain different types of photodiodes and photodetectors		3, 4, 5	Apply; Analyze; Evaluate;		
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics						
		PO1	PO2	PO3	PSO1	PSO2	PSO3
	CO1	3	2	1	3	1	2
	CO2	3	1	2	3	1	2
	CO3	1	2	3	3	1	2
	CO4	1	3	2	3	1	2
	CO5	1	2	3	3	1	2
Syllabus Details:				Text/Ref. Books	Hrs	CO(s)	
Unit 1	Review of Semiconductor Physics: Energy Bands, Density of States, Fermi-level, PN Junction, Homo and Hetero Junction, Quantum Wells. Semiconductor Optoelectronic materials, Electron-hole pairs			T1, T3, R4	9	1	
Unit 2	Light Emitting Diodes: The electroluminescence Process, LED materials, Device configuration and Efficiency, LED structures, LED performance characteristics, Frequency response and Modulation bandwidth. LEDs for display and Lighting.			T1, T3, R5	9	2	
Unit 3	Semiconductor Lasers: Junction Laser Operating Principles, Threshold Current, Heterojunction Laser, Distributed Feedback Lasers and Distributed Bragg Reflector, Ring Lasers: Single and Double, Master Oscillator Power Amplifier. VCSELS and Laser Diode Arrays. Advanced Semiconductor Laser: Quantum Well and Quantum Cascade Laser, Laser Modulation Bandwidth, Semiconductor Optical Amplifier (SOA)			T1, T2, R5	9	3	
Unit 4	Modulation and Switching Devices: Analog and Digital Modulation of light sources, Franz-Keldysh and Stark-effect based Modulators, QW Electro-absorption modulator.			T-2, T-3	9	4	
Unit 5	Photodetectors: Types of photodetectors, Photoconductors, Junction photodiode, PIN photodiode and APD, Quantum Well IR Detectors, High Speed Measurements, Detectors for long wavelength operation, Wavelength selective detection.			T-1, T-2, R-4	9	5	

	Coherent detection. CMOS, iCCDs and PICs.			
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995). 2. G. Ghione, Semiconductor Devices for High-Speed Optoelectronics, Cambridge University Press (2009) 3. A. Yariv and P. Yeh, Photonics: Optical Electronics in Modern Communication, Oxford University Press (2007), 6th Ed., Ch.15-17.			
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	1. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007), Ch.16, 17. 2. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021). 3. Streetman, Ben, and Sanjay Banerjee. Solid state electronic devices. Pearson Higher Ed, 2015. 4. 'Introduction to semiconductor optics', Nasser Peyghambarian, 1993, Prentice Hall edition			

Core Courses-Semester I	
Subject Code	AP 614
Subject Title	Optical Electronics
Credit	03
Teaching Scheme	Lectures: 03 hours/week
Evaluation Pattern	1. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 2. One Final Evaluation at the End of the Term 50 Marks 3. Assignments/Seminars: 10 Marks
Total Marks	100 Marks
Pre-requisite	Basic Physics Knowledge
About the Course	This course provides an in-depth study of Optical Electronics , which are central to controlling and manipulating light using electric fields. It emphasises the underlying physical principles of the electro-optic/acousto-optics/Magneto-optics effect, material properties, and the integration of these devices into complex optical systems used in communication, sensing, imaging, and signal processing. Students will explore the design, operation, and application of devices such as electro-optic/acousto-optic/Magneto-Optic modulators, phase shifters, and deflectors.
Course Objectives	• Explain the physical principles of laser operation, including the quantum mechanics of light-matter interaction. • Understand the role of gain media, pumping mechanisms, and optical resonators in laser systems. • Analyze the behaviour of laser beams, including coherence, mode structure, and beam propagation. • Compare different types of lasers (gas, solid-state, semiconductor, fiber laser and amplifiers) and their applications. • Solve quantitative problems involving laser parameters such as output power, threshold conditions, and efficiency.
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create
CO Title	Bloom's Level and Descriptor

	CO1:	Understand the physical principles of electro-optic effects in different materials.	Understand (Level 2)							
	CO2:	Analyze and design electro-optic devices such as modulators, switches, and deflectors.	Apply (Level 3)							
	CO3:	Apply knowledge of electro-optic components to real-world systems in communications and sensing	Apply (Level 3)							
	CO4:	Solve quantitative problems related to laser threshold conditions, gain, power output, and efficiency.	Evaluate (Level 5)							
	CO5:	Model the behavior and performance of electro-optic systems, including bandwidth and modulation depth.	Apply (Level 6)							
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics									
		PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
	CO1	3	2	-	-	-	-	3	1	2
	CO2	1	3	2	-	-	-	3	1	2
	CO3	-	1	-	2	-	3	3	1	2
	CO4	2	3	1	-	-	-	3	1	2
	CO5	2	1	-	-	3	-	3	1	2
Syllabus Details:							Text/Ref. Books	Hrs	CO(s)	
Unit 1	Electromagnetic fields and Anisotropic media: Wave equation, Plane waves, Reflection and Refraction of plane waves, Fresnel Formula, Wave propagation in stratified medium, propagation of Electromagnetic waves in Uniaxial and biaxial crystals, the dielectric constant tensor and the ‘index ellipsoid’						T1, T2	6	1	
Unit 2	Polarisation of light and Basic optical components: Electromagnetic theory of light, Dielectric media, Monochromatic EM waves, Absorption and dispersion, Polarisation of light, Jones Calculus, Poincare sphere. Polarisers, Quarter, Half, and Full waveplates, Beam splitters: polarising and non-polarising, wavelength filters, dichroic mirrors, Lenses.						T1, T2	12	2	
Unit 3	Electro-optics: Basic principles: Pockels and Kerr effects, Electro-optic devices: modulators, switches, and scanners, E.O. effect in liquid crystals; LCDs and SLMs, Applications. Hands-On on Application of Pockels Cell in Laser						T1, T2, R1, and R2	10	3	
Unit 4	Magneto-optics: Principles, Faraday effect, Gyrotropic permittivity, Kerr rotation and Kerr ellipticity, Applications.						T1, T2, R1, and R2	9	4 and 6	
Unit 5	Acousto-optics: Strain waves in solids and liquids, the strain-optic tensor; theory of Raman-Nath and Bragg diffraction; small-angle and large-angle Bragg diffraction. Accousto-optic devices: Modulators, deflectors, scanners, interconnections, and acousto-optic tunable filters. Hands-On on Application of Acousto-optics Device in Laser						T1, T2, R1, and R2	9	5	
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press,1989. References 2. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006.									
Reference Book	1. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)									

(Should Know) Ref. as (Rx) in the Syllabus	2. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000.

Lab Course-Semester I																																																	
Subject Code	AP 615L																																																
Subject Title	Laser and Electro Optics - I																																																
Credit	03																																																
Teaching Scheme	Lectures: 06 hours/week																																																
Evaluation Pattern	1. Continuous Evaluations: Experiments, Lab Records and Vive-voce 40 Marks (20 + 10 + 10) 2. Mini-Project and Term Work Evaluations: 10 Marks 5. One Final Evaluation at the End of the Term 50 Marks																																																
Total Marks	100 Marks																																																
Pre-requisite	Laser safety tutorials/video demonstration of Laser safety followed by written test																																																
About the Course	The Laser and Electro-Optics Laboratory course provides hands-on experience with the principles and applications of lasers, optical components, and electro-optic devices. It is designed to complement theoretical knowledge in optics and photonics with practical laboratory skills, emphasizing experimental methods, measurement techniques, and data analysis. This lab-centric course bridges the gap between classroom learning and real-world photonics applications, allowing students to explore the behaviour of light and optical systems through direct experimentation.																																																
Course Objectives	1. Understand the Principles of Laser Operation 2. Gain Proficiency in Optical Alignment and Measurement 3. Operate and Characterize Lasers and Electro-Optic Devices 4. Measure and Interpret Optical Phenomena 5. Develop Laboratory and Analytical Skills																																																
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create																																																
CO Title								Bloom's Level and Descriptor																																									
	CO1:	To make students familiar with various experiments in the field of lasers and electro-optics						Understand (Level 2)																																									
	CO2:	To make students realize usage of various optical components and system design						Analyze (Level 4)																																									
	CO3:	To make students learn practical on hands-on setup						Apply (Level 3)																																									
	CO4:	To make student understand to generate a systematic data and report in scientific method						Apply, Analyze (Level 3, Level4)																																									
	CO5:	To analyze results obtained and verify with theory values and provide meaningful conclusion						Evaluate (Level 5)																																									
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics <table><tr><td></td><td>PO1</td><td>PO2</td><td>PO3</td><td>PO4</td><td>PO5</td><td>PO6</td><td>PSO1</td><td>PSO2</td><td>PSO3</td></tr><tr><td>CO1</td><td>1</td><td>2</td><td></td><td></td><td></td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO2</td><td>1</td><td>3</td><td>2</td><td></td><td></td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO3</td><td>1</td><td>2</td><td>2</td><td>1</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td></tr></table>										PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3	CO1	1	2				3	3	1	2	CO2	1	3	2			3	3	1	2	CO3	1	2	2	1	2	3	3	1	2
	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3																																								
CO1	1	2				3	3	1	2																																								
CO2	1	3	2			3	3	1	2																																								
CO3	1	2	2	1	2	3	3	1	2																																								

		CO4	1	3	3	1	3	2	3	1	2	
		CO5	1	2	2	1	2	3	3	1	2	
Syllabus Details:									Text/Ref. Books	Hrs	CO(s)	
List of Experiments:												
1.	Analog and Digital Fiber Optic Link Design									6	CO1	
2.	Michelson Interferometer									6	CO1	
3.	Determination of Numerical Aperture and V Number of single mode & multimode fiber.									6	CO1	
4.	Micro and Macro bending in Optical Fibers									6	CO2	
5.	Beam Alignment and Collimation									6	CO2	
6.	Measurements of Insertion losses in Isolator, Coupler and Multiplexer									6	CO2	
7.	Fiber cleaving and Splicing techniques for step index single mode and multimode fibers.									6	CO2	
8.	Bit error rate and eye pattern									6	CO2	
9.	Characterization of Photodiodes									6	CO3	
10.	Attenuation and dispersion of optical fibers									6	CO3	
11.	Beam parameters of Laser diodes (Beam width and divergence)									6	CO3	
12.	Wavelength Division Multiplexing (WDM), Wavelength Division Demultiplexing (DEMUX), Add-Drop Multiplexing									6	CO4	
13.	Mini Project									6	CO1-CO5	
Text Books (Must Know), Ref. as (Tx) in the Syllabus		1. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press, 1989. References 2. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006. 3. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008										
Reference Book (Should Know) Ref. as (Rx) in the Syllabus		1. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007) 2. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000. 3. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998 4. J.P. Dakin & B Culshaw, Optical Fiber Sensors, Vol. 1&2., Artech House 1998 5. K.T.V. Grattan & B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, 1988										

CORE Courses-Semester II	
Subject Code	AP 616
Subject Title	Laser Applications
Credit	3
Teaching Scheme	Lectures: 03 hours/week
Evaluation Pattern	1. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks

	2. One Final Evaluation at the End of the Term 50 Marks						
	4. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks						
Total Marks	100 Marks						
Pre-requisite	Fundamental knowledge in lasers						
About the Course							
Course Objectives							
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create						
CO Title			Level	Descriptor			
	CO-1	Familiarize to a variety of applications on lasers	L1, L2	Remember, Learn			
	CO-2	Interpret how laser-based metrological techniques work	L1, L2	Remember, Learn			
	CO-3	Understand laser spectroscopy applications	L3, L4	Apply, Analyse			
	CO-4	Investigate various methods of how a laser can be used for defence applications	L4, L5	Analyse, Evaluate			
	CO-5	Summarize different applications of lasers	L5, L6	Evaluate, Create			
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics						
		PO1	PO2	PO3	PSO1	PSO2	PSO3
	CO1	3	3	3	3	1	2
	CO2	3	2	3	3	1	2
	CO3	3	2	3	3	1	2
	CO4	3	3	3	3	1	2
	CO5	3	3	3	3	1	2
1 - Slightly; 2 - Moderately; 3 - Substantially							
Syllabus Details:			Text/Ref. Books	Hrs	CO(s)		
Unit 1	Laser Metrology: Laser for measurement of distance, length, velocity, acceleration; rotation sensing; RLG and FOG.			6	CO1		
Unit 2	Laser Spectroscopy: IR absorption Spectroscopy, Laser Raman spectroscopy, Laser induced breakdown spectroscopy (LIBS), laser-induced fluorescence (LIF), Tunable diode laser spectroscopy (TDLS), Terahertz spectroscopy, Photoacoustic spectroscopy, Instrumentation in laser spectroscopy, Isotope Separation & Enrichment. Bio-Medical Application of Lasers			12	CO1		
Unit 3	Holography: Holographic interferometry and applications; Holography for non – destructive testing – Holographic components			6	CO1 CO2		
Unit 4	Industrial Application of Laser: Laser cutting, Laser welding, Laser drilling, Laser marking, Photolithography, Laser-based unmanned ground vehicles			9	CO3, CO4		
Unit 5	Defence Applications: Low power laser applications including Laser Range finders-LRF (DPSSL, Eye Safe & High PRF) & Laser Target Designators; Dazzlers, Laser Warning receivers, Infrared counter measures, Laser Guidance; Laser-based navigation; Laser-based imaging; Laser-based remote sensing: Laser radar, laser radar seekers, LIDAR basic concept and applications, AI based opt mechanics, Laser-based 3D printing and Directed Energy Weapon applications			12	CO4, CO5		

Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. J.F. Ready, Industrial Applications of Lasers. Academic Press, 1997 2nd Edition 2. G.K. Ackermann & J. Eichler, Holography: A practical approach, John Wiley & sons, 2008 3. H. Wichel, Laser Beam Propagation in the Atmosphere, SPIE Press 1990
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	

Core Courses-Semester II		
Subject Code	AP 617	
Subject Title	Computational Photonics	
Credit	03	
Teaching Scheme	Lectures: 03 hours/week	
Evaluation Pattern	3. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 4. One Final Evaluation at the End of the Term 50 Marks 5. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks	
Total Marks	100 Marks	
Pre-requisite	Basic Physics Knowledge	
About the Course	Computational Photonics is an advanced, interdisciplinary course that focuses on the use of computational methods to analyze, design, and simulate photonic devices and systems. It blends principles from optics, electromagnetics, numerical methods, and computer science to tackle complex problems in modern photonics, which includes areas like optical waveguides, fiber optics, photonic crystals, meta surfaces, and Optical system design.	
Course Objectives	- Understand the Fundamental Principles of Light-Matter Interaction - Introduce Numerical Methods for Solving Electromagnetic Problems - Bridge Theory and Simulation in Photonic Systems - Develop Proficiency in Simulation Tool - Enable Design and Optimization of Photonic Devices and optical systems	
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create	
CO Title		Bloom's Level and Descriptor
	CO1: Understand the principles and limitations of various computational methods in photonic	Understand (Level 2)
	CO2: Design and analyze photonic structures using numerical simulations	Apply (Level 3)
	CO3: Develop and validate computational models for optical devices	Analyze (Level 6)
	CO4: Apply knowledge of electro-optic components to real-world systems in communications and sensing	Apply (Level 3)
	CO5: Interpret simulation results and apply them to real-world photonic problems	Evaluate (Level 5)

Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics						
		PO1	PO2	PO3	PSO1	PSO2	PSO3
	CO1	3	2	1	3	1	2
	CO2	3	1	2	3	1	2
	CO3	1	2	3	3	1	2
	CO4	1	3	2	3	1	2
	CO5	1	2	3	3	1	2
Syllabus Details:					Text/Ref. Books	Hrs	CO(s)
Unit 1	Mode Solver Method: Theory of fully vectorial mode solvers in 2D and 3D structures, low-index polymer waveguides, high-index silicon (SOI) and GaAs/AlGaAs waveguides, buried, etched (rib, ridge), and diffused geometries commonly used in opto-electronics slot waveguides, slanted-wall and graded structures.				T1, T2, S1	6	1-5
Unit 2	FDTD Method: Theory and working of FDTD method, Tutorials on photonics band gap simulation: 2D and 3D of different crystal lattices.				T1, T2 and S1	12	1-5
Unit 3	Fiber Optics Modelling: Simulation and modelling of single-mode and multimode optical fiber using mode solver, FBG and Chirped FBG synthesis, photonic crystal fiber simulation				T1, T2, T3 and S1	10	1-5
Unit 4	Optical System Design 1: Geometrical Optics; Ray Tracing, Lens makers formula, First Order Optics, Wave Optics; Gaussian beams, Interference & diffraction, Diffraction effects, Aberration Theory; Spherical, Coma, Astigmatism, Field curvature, Distortion				T4 and S2	9	1-5
Unit 5	Optical System Design 2: Telescope; Modeling the telescope, Analyzing & optimizing the performance, Polychromatic beam expander; Modeling the set up with diff fields & wls, Analyzing the performance, Optimizing the expander system, High Energy lasers STOP analysis, Environmental effects				T4 and S2	9	1-5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. S. Sujecki, Photonics Modelling and Design, CRC Press, 2015. 2. K. Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2000. 3. A. Taflove, Computational Electrodynamics: The Finite-Difference Time Domain Method. Norwood, MA: Artech House, 1995. 4. Robert E Fischer, Bijana Tadic: Optical System Design, 2 nd edition, Mcgrow Hill eduction, 2008						
Software Resources	1. Ansys Lumerical: Mode Solver and FDTD 2. Zemax Opticstudio						

Lab Course-Semester II	
Subject Code	AP 618L
Subject Title	Laser and Electro Optics - II
Credit	03
Teaching Scheme	Lectures: 06 hours/week
Evaluation Pattern	1. Continuous Evaluations: Experiments, Lab Records and Vive-voce 40 Marks (20 + 10 + 10) 2. Mini-Project and Term Work Evaluations: 10 Marks 6. One Final Evaluation at the End of the Term 50 Marks
Total Marks	100 Marks

Pre-requisite	Laser safety tutorials/video demonstration of Laser safety followed by written test										
About the Course	The Laser and Electro-Optics Laboratory course provides hands-on experience with the principles and applications of lasers, optical components, and electro-optic devices. It is designed to complement theoretical knowledge in optics and photonics with practical laboratory skills, emphasizing experimental methods, measurement techniques, and data analysis. This lab-centric course bridges the gap between classroom learning and real-world photonics applications, allowing students to explore the behaviour of light and optical systems through direct experimentation.										
Course Objectives	1. Understand the Principles of Laser Operation 2. Gain Proficiency in Optical Alignment and Measurement 3. Operate and Characterize Lasers and Electro-Optic Devices 4. Measure and Interpret Optical Phenomena 5. Develop Laboratory and Analytical Skills										
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create										
CO Title								Bloom’s Level and Descriptor			
	CO1:	To make students familiar with advanced experiments in the field of lasers and electro-optics							Understand (Level 2)		
	CO2:	To make students realize usage of complex optical components and system design							Analyze (Level 4)		
	CO3:	To make students learn about real-time applications in optical communication							Apply (Level 3)		
	CO4:	To make students realize systematic data and report presentation in scientific methods							Apply, Analyze (Level 3, Level4)		
	CO5:	To analyze results obtained and verify with theory values and provide meaningful conclusion							Evaluate (Level 5)		
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics										
		PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3	
	CO1	1	2				3	3	1	2	
	CO2	1	3	2			3	3	1	2	
	CO3	1	2	2	1	2	3	3	1	2	
	CO4	1	3	3	1	3	2	3	1	2	
	CO5	1	2	2	1	2	3	3	1	2	
Syllabus Details:							Text/Ref. Books	Hrs	CO(s)		
	List of Experiments:										
	1.	Characterization of Fiber Bragg grating							6	CO1	
	2.	Study of Time Division Multiplexing of digital signals							6	CO1	
	3.	Power budget analysis using Optical Time Domain Reflectometer (OTDR)							6	CO3	
	4.	Study of a Wavelength Division Multiplexing (WDM) in optical fiber link							6	CO2	

	5.	Exercise of Add/drop multiplexer for various wavelengths	6	CO2
	6.	Study of Bit error rate and Eye pattern analysis	6	CO2
	7.	Line coding and decoding, voice coding	6	CO2
	8.	Setting up a Free space Laser Communication experiment link	6	CO2
	9.	Determination of Electro-optic effect coefficients through Pockel's effect	6	CO3
	10.	Measurement of third order nonlinear optical coefficient using Z-scan	6	CO3
	11.	Beat length measurement in birefringent fibers.	6	CO3
	12.	Measurement of insertion loss of an isolator, coupler and multiplexer	6	CO4
	13.	Mini Project	6	CO1-CO5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press, 1989. References 2. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006. 3. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008 4. G. P. Agarwal, Fiber Optic Communication Systems, John Wiley & Sons, 2002. 5. Optical Fiber Communications – John M. Senior, PHI, 2nd Edition, 2002			
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	1. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007) 2. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000. 3. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998.			

Elective Courses-Semester II	
Subject Code	AP 619
Subject Title	Terahertz Devices and Applications
Credit	03
Teaching Scheme	Lectures: 03 hours/week
Evaluation Pattern	1. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 2. One Final Evaluation at the End of the Term 50 Marks 3. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks
Total Marks	100 Marks
Pre-requisite	B.Sc. Physics or Engineering Physics Knowledge
About the Course	THz devices applications is a course giving a better understanding the less explored THz field in EM spectrum. The course provides information of properties of THz radiation, sources, detectors and different spectroscopic methods. It also explains the applications of THz in communication. The course will start with the introduction to properties of EM radiation and Maxwell equations. A introduction to THz is provided by discussing the properties of these rays (waves) in different media, advantages and disadvantages of the THz radiation

	Later, THz sources which works with different principles of Electronic (PINN diodes, HBT, HEMT), Optical based (Photomixers, NLO Crystals), Optoelectronic based (THz Quantum cascade Lasers, Photoconductive antenna), Different types of PCAs are discussed with the advantages of the PCA, the noise levels of the above explained THz sources are compared. In unit 3, different THz detectors are discussed based thermal (Hot electron Bolometer, Pyro-detector), Optical (Electro-optic sampling), electronic (Superconducting tuning circuitries, HEB heterodyne receivers), The concepts related to Terahertz MMICs: Theory and design, Terahertz detectors based on photonics are discussed thoroughly with the application-based comparison. Furthermore, the THz components such as Filters, Waveguides, Beam splitters, Beam combiners, polarizers, Mirrors, isolators, circulators, and Cameras, along with material properties, are explained briefly. The Fabrication Technologies of Metamaterial THz devices, Metamaterials and plastic fibers, HEMT cryogenic amplifiers: Theory and design, Antennas are explained. The application of Spintronic materials as THz components has also been discussed from the references of research articles. Finally, in Unit 5, THz applications in industry, imaging, and security are shown. The advantages and future scope of THz in 6G communication are explained thoroughly. The advantages of THz imaging on the current imaging setup are detailed with practical examples This course is helping M. Tech. ‘Laser and Electro-optics’ and ‘Sensor-Technology’ students and similar branches to understand how the THz field and its equipment are working to fulfill the current needs of our society.						
Course Objectives	- To impart basic knowledge of Terahertz Technology - To introduce the THz Sources, THz Detectors, THz Components. - To enable the students to understand application of THz technology in imaging, sensing and communication.						
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create						
CO Title				Level	Descriptor		
	CO1:	Introduction to the concepts of terahertz technology		1, 2	Remember; Understand		
	CO2:	Analyze the working principle of different types of terahertz signal sources		2, 3	Understand; Apply		
	CO3:	Examine the working mechanism of different types of terahertz detectors		2, 3	Understand; Apply		
	CO4:	Illustrate the practical implementation of fabrication of components and circuits for terahertz systems		3, 4	Apply; Analyze		
	CO5:	Summarize different applications of terahertz technology for imaging, sensing and communications		3, 4, 5	Apply; Analyze; Evaluate;		
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics						
		PO1	PO2	PO3	PSO1	PSO2	PSO3
	CO1	3	1	2	3	1	2
	CO2	3	1	2	3	1	2
	CO3	1	2	3	3	1	2
	CO4	1	3	2	3	1	2
	CO5	1	2	3	3	1	2
Syllabus Details:				Text/Ref.	Hrs	CO(s)	

		Books		
Unit 1	Basics of Terahertz Technology: Electromagnetic radiation and propagation fundamentals, Introduction to terahertz technology, Background, Terahertz gap, Key technological issues for terahertz technology, Advantages and limitations of terahertz waves, Material properties at mm and sub-mm frequencies	T1, T3, R1	9	1
Unit 2	Terahertz Sources: Terahertz sources based on electronics: Diodes, transistors, resonant tunnelling diodes, vacuum electronics; Terahertz sources based on photonics: Non-linear crystals, quantum cascade lasers, plasma-based source; Terahertz sources based on optoelectronics: Photomixer, photoconductive antenna and its types; Noises at terahertz frequencies in different sources	T1, T3, R1	9	2
Unit 3	Terahertz Detectors: Terahertz detectors based on electronics: HOT electron bolometer, Heterodyne SIS receivers: Theory and design, Superconducting tuning circuitries, HEB heterodyne receivers: Theory and design, Terahertz MMICs: Theory and design, Terahertz detectors based on photonics	T1, T2, R2	9	3
Unit 4	Terahertz Components: Terahertz components: Metamaterials and plastic fibers, HEMT cryogenic amplifiers: Theory and design, Antennas, Filters, Waveguides, Beam Splitter, Beam Combiner, Polarizer, Mirrors, Isolator, Circulator, Cameras, Fabrication Technologies, Metamaterial THz devices, Spintronic THz components.	T-2, T-3	9	4
Unit 5	Terahertz Applications: Terahertz applications: Time domain Colinear and Non-colinear terahertz spectroscopy, Optical-pump-THz-probe Spectroscopy, Terahertz Imaging, Terahertz sensing and analysis, Terahertz wireless communication, Terahertz remote-sensing, 3D terahertz tomography system, Industrial applications, 6G Communication, Space Communication, Cutting-edge terahertz technologies	T-1, T-2, R-1	9	5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. A. Rostami, H. Rasooli, H. Baghban, Terahertz Technology: Fundamentals and Applications, Germany, Springer, 2011. 2. R. E. Miles, P. Harrison, D. Lippens, Terahertz Sources and Systems “, Dordrecht: Kluwer, Springer, 2000. 3. K. Sakai, Terahertz Optoelectronics, Springer, 2004.			
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	1. H.-J. Song, T. Nagatsuma, Handbook of Terahertz Technologies, Devices and applications, Pan Stanford Publishing Pte. Ltd., 2015. 2. D. Saeedkia, Handbook of Terahertz Technology for Imaging, Sensing and Communications, Woodhead Publishing, 2013.			

Elective Courses-Semester II	
Subject Code	AP 620
Subject Title	Nanophotonics
Credit	03
Teaching Scheme	Lectures: 03 hours/week
Evaluation Pattern	1. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks

	2. One Final Evaluation at the End of the Term 50 Marks																																																				
	3. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks																																																				
Total Marks	100 Marks																																																				
Pre-requisite	Basic Knowledge in Optics																																																				
About the Course	This course explores the interaction of light with nanostructured materials and devices. Students will learn fundamental concepts such as quantum confinement, surface plasmons, and the unique optical properties of metamaterials and photonic crystals. The course integrates theoretical frameworks with practical applications in modern optical and electronic devices, emphasizing design principles and emerging technologies.																																																				
Course Objectives	- Introduce students to the interaction of light with nanostructures. - Understand the physical principles and applications of photonic bandgap materials, metamaterials, and surface plasmons. Explore quantum confinement and its role in nanostructure optical behavior																																																				
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create																																																				
CO Title			Level	Descriptor																																																	
	CO1:	Understand how nanoscale dimensions affect optical behavior via quantum confinement.	1, 2	Remember; Understand																																																	
	CO2:	Explain the concept of left-handed metamaterials and predict their unique optical effects.	2, 3	Understand; Apply																																																	
	CO3:	Analyze optical behavior of metamaterials including negative index and imaging beyond diffraction limits.	2, 3	Understand; Apply																																																	
	CO4:	Explain the principles of SPR and its use in high-sensitivity detection platforms.	3, 4	Apply; Analyze																																																	
	CO5:	Analyze the formation and implications of photonic bandgaps in periodic media.	3, 4, 5	Apply; Analyze; Evaluate;																																																	
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics <table><tr><td></td><td>PO1</td><td>PO2</td><td>PO3</td><td>PSO1</td><td>PSO2</td><td>PSO3</td></tr><tr><td>CO1</td><td>3</td><td>3</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO2</td><td>3</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO3</td><td>3</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO4</td><td>3</td><td>3</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO5</td><td>3</td><td>3</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td colspan="7">1 - Slightly; 2 - Moderately; 3 - Substantially</td></tr></table>					PO1	PO2	PO3	PSO1	PSO2	PSO3	CO1	3	3	3	3	1	2	CO2	3	2	3	3	1	2	CO3	3	2	3	3	1	2	CO4	3	3	3	3	1	2	CO5	3	3	3	3	1	2	1 - Slightly; 2 - Moderately; 3 - Substantially						
	PO1	PO2	PO3	PSO1	PSO2	PSO3																																															
CO1	3	3	3	3	1	2																																															
CO2	3	2	3	3	1	2																																															
CO3	3	2	3	3	1	2																																															
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CO5	3	3	3	3	1	2																																															
1 - Slightly; 2 - Moderately; 3 - Substantially																																																					
Syllabus Details:			Text/Ref. Books	Hrs	CO(s)																																																
Unit 1	Basics of Nanophotonics Photons and electrons		Text Book-1 Chapter 1	08 Hours	CO1																																																

	- Quantum confinement effects in nanostructures 2D, 1D, and 0D structures: examples, fabrication techniques, and key properties - Relationship between structure size and optical properties			
Unit 2	Fundamentals of Metamaterials - Definition of Metamaterials (MTMs) and Left-Handed Materials (LH MTMs) - Left-Handedness from Maxwell's Equations - Negative refraction and associated phenomena - Entropy and the second law of thermodynamics Doppler effect and Čerenkov radiation in LH media	Text Book 2, Ch-1 Text Book 3, Ch-3	06 Hours	CO2
Unit 3	Metamaterials in Optics - Optical properties of metal-dielectric composites - Optical magnetism and negative permeability - Negative refractive index and Snell's law reversal - Perfect lens theory and super-resolution imaging Cloaking devices: theory and experimental demonstrations	Reference -2	8 Hours	CO3
Unit 4	Surface Plasmon Resonance (SPR) - Evanescent waves and total internal reflection - Surface plasmon dispersion relations - Resonance conditions and excitation techniques - Surface plasmon properties and decay length SPR spectroscopy and applications in biosensing	Text Book 1 Ch 6 Text Book 3 Ch 2	8 Hours	CO4
Unit 5	Photonic Band Gap Crystals Periodic dielectric structures and Bragg reflection	Text Book 3	8 Hours	CO5

	- Formation of photonic band gaps (PBG) 1D, 2D, and 3D photonic crystals - Bloch states and Brillouin zone analysis			
	Applications: filters, waveguides, light localization			
Text Books (Must Know), Ref. as (Tx) in the Syllabus	- Nanophotonics by P.N. Prasad - Metamaterials: Physics and Engineering Explorations" by Nader Engheta and Richard W. Ziolkowski - Photonic Crystals: Molding the Flow of Light by J.D. Joannopoulos et al.			
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	- Principles of Nano-Optics by Lukas Novotny and Bert Hecht (Chapter on Plasmonics) - Pendry, J.B., "Negative Refraction Makes a Perfect Lens", Phys. Rev. Lett. 85, 3966 (2000)			

Elective Courses-Semester II				
Subject Code	AP 621			
Subject Title	Fiber Optic Devices & systems			
Credit	03			
Teaching Scheme	Lectures: 03 hours/week			
Evaluation Pattern	- Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks - One Final Evaluation at the End of the Term 50 Marks - Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks			
Total Marks	100 Marks			
Pre-requisite	Basic Knowledge in Optics			
About the Course				
Course Objectives				
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create			
CO Title		Level	Descriptor	
	CO1:	Understand the basics concepts of Fiber Optic Communication	1, 2	Remember; Understand
	CO2:	Understand all the sub-components of Fiber Optics	2, 3	Understand; Apply
	CO3:	Examine the working mechanism of Fiber Optics	2, 3	Understand; Apply
	CO4:	Illustrate the practical implementation of Fiber Optic Communication	3, 4	Apply; Analyze
	CO5:	Summarize different applications of Fiber Optic Communication	3, 4, 5	Apply; Analyze; Evaluate;

Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics						
		PO1	PO2	PO3	PSO1	PSO2	PSO3
	CO1	3	3	3	3	1	2
	CO2	3	2	3	3	1	2
	CO3	3	2	3	3	1	2
	CO4	3	3	3	3	1	2
	CO5	3	3	3	3	1	2
1 - Slightly; 2 - Moderately; 3 - Substantially							
Syllabus Details:					Text/Ref. Books	Hrs	CO(s)
Unit 1	Optical Fibers: Light Propagation in Optical Fibers, Optical fiber Modes and Configurations, Mode Theory for Circular waveguides, SM and GI Fibers, Fiber Materials, PhC fibers, Fiber fabrication. Optical Fibers Characteristics: Fiber Attenuation, Absorption losses, scattering losses, Radiation losses, Bending losses, Measurement of losses, Dispersion in fibers, Effect of dispersion in the communication link, Dispersion reduction, and compensation techniques.				T1, T3, R1	12	CO1
Unit 2	Power Launching and Coupling: Source to Fiber launching and Launching Schemes for Coupling Improvements. Fiber to Fiber joints, Laser coupling to SM fiber, Fiber splicing, Optical Fiber Connector. Optical Receivers: Basic Concepts, Common Photodetectors, Receiver Design, Receiver Noise, Coherent Detection, Receiver Sensitivity, Sensitivity Degradation, Receiver bandwidth, and Performance				T1, T3, R1	9	CO1
Unit 3	Fiber Amplifier: Optical Amplification in rare-earth-doped fibers, Types of Fiber Amplifiers, EDFA, Amplifier Noise, Optical SNR, System Application, Raman Amplifiers, Wideband Optical Amplifier				T1, T2, R2	9	CO1 CO2
Unit 4	Optical Fiber Sensors: Introduction, Classification and Types of Optical Fiber Sensors, Sensor Modulation techniques, Fiber Bragg Grating Sensors: Principle and Applications.				T-2, T-3	9	CO3, CO4
Unit 5	Overview of Optical Fiber Communication: Lightwave communications, Optical Spectrum Bands, and Visible Units, Network Information rate and WDM concepts. Key Elements of fiber optics system, Standards for Optical fiber communications.				T-1, T-2, R-1	9	CO4, CO5
Text Books (Must Know), Ref. as (Tx) in the Syllabus		1. A.K. Ghatak & K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press 1998 2. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008 3. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998 4. J.P. Dakin & B Culshaw, Optical Fiber Sensors, Vol. 1&2., Artech House 1998 5. K.T.V. Grattan & B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, 1988 6.					
Reference Book (Should Know) Ref. as (Rx) in the Syllabus							

Elective Courses-Semester II																																																				
Subject Code	AP 622																																																			
Subject Title	Free Space Optical Communication																																																			
Credit	03																																																			
Teaching Scheme	Lectures: 03 hours/week																																																			
Evaluation Pattern	7. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 8. One Final Evaluation at the End of the Term 50 Marks 9. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks																																																			
Total Marks	100 Marks																																																			
Pre-requisite	Basic Knowledge in Optics																																																			
About the Course																																																				
Course Objectives																																																				
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create																																																			
CO Title			Level	Descriptor																																																
	CO1:	Interpret the concepts of Free Space Optical Communication	L1, L2	Remember, Learn																																																
	CO2:	Understand all the sub-components	L1, L2	Remember, Learn																																																
	CO3:	Examine the working mechanism of FSOC	L3, L4	Apply, Analyse																																																
	CO4:	Illustrate the practical implementation of FSOC	L4, L5	Analyse, Evaluate																																																
	CO5:	Summarize different applications of FSOC such as VLC/UWOC	L5, L6	Evaluate, Create																																																
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics																																																			
	<table><tr><td></td><td>PO1</td><td>PO2</td><td>PO3</td><td>PSO1</td><td>PSO2</td><td>PSO3</td></tr><tr><td>CO1</td><td>3</td><td>3</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO2</td><td>3</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO3</td><td>3</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO4</td><td>3</td><td>3</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO5</td><td>3</td><td>3</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td colspan="7">1 - Slightly; 2 - Moderately; 3 - Substantially</td></tr></table>					PO1	PO2	PO3	PSO1	PSO2	PSO3	CO1	3	3	3	3	1	2	CO2	3	2	3	3	1	2	CO3	3	2	3	3	1	2	CO4	3	3	3	3	1	2	CO5	3	3	3	3	1	2	1 - Slightly; 2 - Moderately; 3 - Substantially					
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1 - Slightly; 2 - Moderately; 3 - Substantially																																																				
Syllabus Details:			Text/Ref. Books	Hrs	CO(s)																																															
Unit 1	Introduction FSOC/OWC, Basic Link configuration of FSOC, various application areas of FSOC, Indoor Channel modelling, various link configurations, Artificial light interference effects in indoor channel, Orbital Angular Momentum-beams, Quantum free-space communication			9	CO1																																															
Unit 2	Channel Modelling -Outdoor channel, Atmospheric channel loss related issues, Atmospheric turbulence effects, Measurement of C_n^2 , Various atmospheric turbulence models, Effects of atmospheric turbulence on laser beam propagation, Realization of atmospheric effects on OWC test beds			9	CO1																																															

Unit 3	Modulation Techniques: Importance of modulation in FSO, various modulation formats, selection criteria for modulation, basic modulation schemes OOK,PPM, PIM, DH-PIM, BPSK etc. and error propagation FSO link Performance under atmospheric turbulence: performance of FSO link in various modulation formats, comparison across the modulation formats, the turbulence-induced penalty in FSO link, Link budget analysis, Power budget analysis		12	CO1 CO2
Unit 4	Mitigation techniques: introduction, aperture averaging, various diversity techniques, spatial diversity, time diversity coding techniques, adaptive optics and other techniques.		9	CO3, CO4
Unit 5	Laser beam Tracking, pointing & acquisition: Acquisition and Tracking systems, System description, Acquisition methodology, tracking and pointing control system, RF cross-link system design, link equation		9	CO4, CO5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. Arun K. Majumdar, Free-Space Laser Communications Principles and Advances. Springer Publications 2. Hemani Kaushal, Free Space Optical Communication. Springer Publication 3. J. Franz and V.K. Jai, Optical Communication Systems. Narosa Publications			
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	1. Morris Katzman, Laser Satellite Communications. Prentice Hall Inc 1991 2. Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, A.K. Jha			

School Of Quantum Technology

SCHOOL OF QUANTUM TECHNOLOGY

M. Tech. in Quantum Computing (Spl: Quantum Communication & Sensing)

About: Quantum Technology is an interdisciplinary domain at the intersection of physics and engineering that leverages the foundational principles of quantum mechanics - such as superposition, entanglement - to develop quantum computing, quantum sensing, quantum cryptography, quantum simulation, quantum metrology, and quantum imaging.

The proposed Quantum Technology program is designed to address the growing national and global demand for skilled professionals in this transformative field. The program aims to develop competent graduates with strong theoretical knowledge and practical expertise to contribute to cutting-edge research and innovation in quantum technologies. The program aspires to position itself as a leading academic and research hub in quantum science and technology, aligned with the national vision for technological self-reliance and global leadership.

Eligibility: B.E / B.Tech. / BSC (Eng.) or equivalent degree in any engineering discipline, **or** 4-year B.S./M.Sc./equivalent degree in any science discipline

Stakeholders:

- i. Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments
- ii. Graduates in the relevant field of science/technology from recognized Universities across the country.

Organization: The M. Tech. Program is of four-semester duration. In each of the first two semesters, there are five core classroom teaching classes, one research methodology, and one experimental laboratory. There will be continuous evaluation examinations, two internal examinations, and a final semester examination for every course. A half-yearly evaluation of the project takes place at the end of the third semester. At the end of the last semester, the student submits a thesis and makes a presentation about the project, which is evaluated by the Internal and External examiners.

SEMESTER I

Sl. No .	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	QT601	Introduction to optics and photonics	3	0	3
2	QT602	Introduction to Quantum Mechanics	3	0	3
3	QT603	Introduction to Quantum Computing	3	0	3
4	QT604	Introduction to Quantum Information Theory	3	0	3
5	QT610	Quantum Technology Laboratory-1	0	6	3
6		Elective-I	3	0	3
7	PGC-601	Research Methodology and IPR	2	0	2
		Total	18	5	20

*L:

Lecture and T/P: Tutorial/Practical

List of Electives

Sl No	Course Code	Course
Elective-I		
1	QT 605	Any one of the NPTEL/SWAYAM course: VLSI Design Flow: RTL to GDS , Analog VLSI Design, Embedded Systems, Embedded Systems Design, Introduction to Embedded Systems Design, Fundamentals of Micro and Nanofabrication, Integrated Photonics devices and circuits, Machine Learning and Deep Learning - Fundamentals and Applications , Workshop on FPGA Architecture and Programming using Verilog HDL or equivalent, and Guest lectures on FPGA hands-on.

SEMESTER II

Sl. No .	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	QT 606	Quantum Communications	3	0	3
2	QT 607	Quantum Computing II	3	0	3
3	QT 611	Quantum Technology Laboratory – II	0	6	3
4		Elective – I	3	0	3
5		Elective – II	3	0	3
6		Elective – III	3	0	3
7	PGC-602		2	0	2
		Total	18	10	20

*L:

Lecture and T/P: Tutorial/Practical

List of Electives

Sl No	Course Code	Course
Electives		
1	QT 621	Classical and Post Quantum Cryptography
2	QT 622	Nonlinear Optics
3	QT 623	Quantum Metrology and Sensing
4	QT 624	Quantum Optics

SEMESTER III

Sl. No.	Course Code	Course	Credits
1	QT 651	M.Tech Dissertation & Seminar – Phase I	20
		Total	20

SEMESTER IV

Sl. No.	Course Code	Course	Credits
1	QT 652	M.Tech Dissertation & Seminar – Phase II	20
		Total	20

PROGRAM OUTCOMES

PO1: Knowledge Acquisition	Demonstrate comprehensive understanding of foundational and advanced principles across all core domains of Quantum Technology, including Quantum Computing, Quantum Communication, and Quantum Sensing and metrology
PO2: Research Competence	Independently design, execute, and interpret research and development activities using quantum resources.
PO3: Expertise and Specialization	Attain knowledge in Quantum Technology that surpasses the competencies acquired in previous academic degrees, aligning with the demands of cutting-edge quantum research labs and industries
PO4: Innovation and Workforce Readiness	Exhibit the capability to contribute to the next-generation quantum workforce by innovating, designing, and deploying quantum-based technologies in emerging sectors of government, defense, and private

PROGRAM SPECIFIC OUTCOMES

PSO1	Demonstrate in-depth knowledge of quantum mechanics, optics, computing, and information theory.
PSO2	Design and implement experimental setups and simulations for quantum communication, sensing, and metrology
PSO3	Apply quantum algorithms and cryptographic protocols in real-time applications such as QKD and quantum communications
PSO4	Utilize FPGA and other embedded systems for signal processing, quantum control systems, and real-time data analysis.

QT 601: INTRODUCTION TO OPTICS AND PHOTONICS

SYLLABUS:

Unit	Syllabus Details
Unit I	Ray optics and Maxwell's equations: Maxwell's equations and solution to Maxwell's equation, Paraxial waves, ray optics and ABCD matrices, Vector and Scalar Potentials, Beam splitters: polarizing and non-polarizing, optical filters, dichroic mirrors, Lenses
Unit II	Wave optics: refractive index, Basic postulates of wave optics, Monochromatic waves, plane waves, spherical waves, paraxial waves, Helmholtz equation, Interference of waves, polarization of light, Stokes vector, Jones Calculus, Polarisers, Quarter and Half waveplates
Unit III	Gaussian and special beams: Complex amplitude of Gaussian beam, Parameters of Gaussian beam, transmission of Gaussian beams through optical components, Hermite-Gauss and Laguerre Gauss beams, nondiffracting beams
Unit IV	Fourier Optics: Propagation of light in free space, Fourier transform using a lens, Fraunhofer and Fresnel diffraction.
Unit V	Lasers: Resonator theory, Basic laser theory, Laser oscillators and amplifiers, Coherence, Diode laser, DPSS lasers, Distributed Fiber Laser and VECSELs
Unit VI	Practical Optical System Design and DAQ: Introduction optical design software (Zemax), Introduction opto-mechanical design software (Solidworks), Introduction to DAQ (Python/Labview)

References

1. B E A Saleh and M C Teich, Fundamentals of Photonics, John Wiley and Sons, 3rd edition, 2019.
2. E. Hecht, Optics, Pearson Education India, 2012
3. D. H. Goldstein, Polarized Light, 3rd edition, Taylor and Francis group, 2011
4. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.
5. A. K. Ghatak and K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press (1998).
6. Zemax introduction (<https://www.youtube.com/user/RadiantZemaxLLC/videos>)
7. LabVIEW Student Edition Textbook by Dr. Robert H. Bishop

COURSE OUTCOMES:

CO-1	Explain the fundamental principles of ray optics and wave optics, and apply them to analyze optical systems using ABCD matrices and wave equations.
CO-2	Analyze the propagation of electromagnetic waves using Maxwell's equations, vector/scalar potentials, and the Helmholtz equation for various optical phenomena.

CO-3	Design and evaluate optical systems using polarizers, waveplates, filters, beam splitters, and optical resonators to manipulate polarization, coherence, and beam parameters.
CO-4	Assess the performance and characteristics of lasers and optical fibers (single-mode, multi-mode, and polarization-maintaining) in the context of Quantum Technology

QT 602: QUANTUM MECHANICS

SYLLABUS:

Unit	Syllabus Details
Unit I	Basic introduction to Quantum Mechanics: Wave-particle duality and matter waves. The double slit experiment. The Stern-Gerlach experiment. The Schrödinger equation, square integrable functions and wavefunctions. Particle in an infinite potential well and bound states. Quantum Tunneling. Position and momentum eigenstates.
Unit II	Linear algebra and complex vectors spaces: Hilbert space. State vectors. Basis sets and the Gram-Schmidt orthogonalization. Unitary operators, operator adjoints and self-adjoint operators (Hermitian operators). Eigenvalues and eigenstates. Eigen basis and spectral decomposition of operators. The Hamiltonian operator. Position, momentum and energy eigenstates. The density operator. Complete set of commuting operators and Observables in quantum mechanics.
Unit III	Quantum Measurements: Projective measurements rank one projectors. Positive Operator Valued Measures. Expectation values and Variance. The Heisenberg uncertainty relations. Pauli's exclusion principle, Fermi and Bose particles.
Unit IV	Harmonic Oscillator, Angular momentum and other problems: The Linear Quantum Harmonic Oscillator. Creation, annihilation operators and number operators their properties. Spin- half quantum systems and Pauli operators. The Angular Momentum problem. Time evolution of quantum systems: The Heisenberg, Schrödinger and Interaction pictures. Time evolution of density operators and the Born formula. Approximation methods.

References

1. Quantum Mechanics, Claude Cohen-Tannoudj, B. Diu and F. Laloë, Volume-I, WILEY-VCH, New York
2. Joachim Stoke, Dieter Suter, Quantum Computing: A *Short* Course from Theory to Experiment, WILEY-VCH GmbH & Co, 2004.
3. L.I Schiff, Quantum Mechanics, McGraw-Hill, 1968.
4. The Principles of Quantum Mechanics, Clarendon Press, Oxford, 1958.
5. David J. Griffiths, Introduction to Quantum Mechanics, Cambridge University Press, 2017
6. Kurt Gottfried, Quantum Mechanics: Fundamentals, Springer (2Ed.), 2003

COURSE OUTCOMES:

CO-1	Explain the foundational principles of quantum mechanics such as wave-particle duality, Schrödinger equation, and quantum states, using simple models like infinite potential wells.

CO-2	Apply the mathematical structure of quantum mechanics using Hilbert spaces, Hermitian operators, eigenvalue problems, and spectral decomposition to describe physical observables.
CO-3	Analyze quantum measurement postulates using projectors and POVMs, and evaluate observables through expectation values, variances, and the Heisenberg uncertainty principle.
CO-4	Solve problems involving the quantum harmonic oscillator, angular momentum, spin- $\frac{1}{2}$ systems, and describe the time evolution of quantum states using different pictures.

QT 603: INTRODUCTION TO QUANTUM COMPUTING

SYLLABUS:

Unit	Syllabus Details
Unit I	Introduction: Introduction to Quantum computing, prehistory of quantum computing, Requirements for quantum computers (DiVincenzo criteria), Quantum Bits, Qubit measurements, qubit evolution, mixed states and density operators, Bloch sphere and Poincare sphere representation of qubits, Tensor product and compound quantum systems, two qubits and multiple qubits systems. Quantum operation on a multiqubit systems, Quantum entanglement, No-cloning theorem, Super-dense coding, Quantum Teleportation.
Unit II	Quantum Gates: Classical Logic gates, Irreversible gates, Universal gates, reversible gates, universal reversible gates, Quantum logic gates, single qubit gates, Rotation gates, multiqubit gates, controlled quantum gates, Universal quantum gates, quantum circuit identities.
Unit III	Quantum Algorithms: Quantum Parallelism, Phase kick-back, Deutsch's problem, Deutsch-Jozsa algorithm, Quantum Fourier transform, Quantum Phase estimation, Grover's search algorithm, Simon's problem, Shor's algorithm.

References

1. Joachim Stoke, Dieter Suter, Quantum Computing: A Short Course from Theory to Experiment, WILEY-VCH GmbH & Co, 2004
2. Chris Bernhardt, Quantum Computing for Everyone, The MIT Press, 2019
3. Nielsen, Michael A.; Chuang, Isaac L., Quantum Computation and Quantum Information Cambridge: Cambridge University Press, 2012
4. Philip Kaye, Raymond La Flamme and Michele Mosca. An Introduction to quantum Computing, Oxford. University Press.

COURSE OUTCOMES:

CO-1	Explain the foundational concepts of quantum computing including qubits, quantum measurement, qubit evolution, and representation using Bloch and Poincaré spheres.
CO-2	Analyze compound quantum systems using tensor products, describe entanglement, and evaluate quantum communication protocols like quantum teleportation and super-dense coding.
CO-3	Apply principles of reversible and quantum logic to design quantum circuits using single and multi-qubit gates, and verify their behavior using quantum circuit identities.

CO-4	Evaluate and implement foundational quantum algorithms such as Deutsch-Jozsa, Grover's search, Shor's algorithm, and Quantum Fourier Transform for computational problem-solving.

QT 604: INTRODUCTION TO QUANTUM INFORMATION THEORY

SYLLABUS:

Unit	Syllabus Details
Unit I	Classical Information theory: Convex functions and Jensen's inequality. Shannon Entropy, mutual entropy and mutual information. Joint and conditional entropy. Data compression and codes. Kolmogorov complexity. Classical channels and Shannon coding theorems. Entropic inequalities.
Unit II	Quantum entropy: Properties of Entropy. Conditional entropy. Quantum mutual information. Additivity sub additivity and strong subadditivity. The Holevo bound. A comparison between classical and quantum information theory.
Unit III	Separable and Entangled states: Von-Neumann entropy. The Bell-state and maximally entangled states. Quantification of Entanglement: Entanglement of formation, Concurrence and entanglement monogamy. Separability of composite states. Entangled states, product states and separable systems. von Neumann entropy and negativity. The Peres-Horodecki theorem. Local unitary operations and classical communication. Quantification of entanglement. Maximally entangled mixed states. The Werner state. Local unitary operations on Bell states.
Unit IV	Quantum decoherence and quantum operations: Fidelity and trace distance measure between quantum states. Quantum systems coupled to environments. Bit flip, Phase Flip and depolarization channels. Amplitude and phase damping. Illustrations in the case of polarization qubits. Quantum state and process tomography with practical illustrations. The operator-sum representation and measurements.

References

1. Elements of Information Theory, Thomas M. Cover and Joy A. Thomas, Wiley India
2. Nielsen, Michael A.; Chuang, Isaac L., Quantum Computation and Quantum Information Cambridge: Cambridge University Press, 2012
3. Benenti, Casati, Strini, Principles of quantum computation and Information, World Scientific.

COURSE OUTCOMES:

CO-1	Explain classical and quantum entropy concepts including Shannon entropy, mutual information, von Neumann entropy, and analyze their implications in information theory.
CO-2	Evaluate quantum correlations using measures such as entanglement of formation, concurrence, and von Neumann entropy; and determine separability using tools like the Peres-Horodecki criterion.

CO-3	Apply the principles of quantum operations and noise models such as bit-flip, phase-flip, and depolarizing channels to describe decoherence and perform quantum state tomography.
CO-4	Compare classical and quantum information theories in terms of entropy, coding theorems, and information bounds (e.g., Holevo bound), and assess the limitations and advantages of each.

QT 610: QUANTUM TECHNOLOGY LABORATORY-I

SYLLABUS:

Sl. No.	Name of experiments
01.	Study of Optical lens and lens systems
02.	Fibre splicing and OTDR measurement
03.	Study of Polarizer, Polarizing and Non-polarizing BS, QW, HW, FW Plates
04.	Polarization properties of laser with and without QW, HW and FW Plates
05.	Fourier Optics
06.	Characterization Diode laser system
07.	Laser beam-divergence and M^2 measurement
08.	Setting up Michelson interferometer
09.	Setting up Mach-Zehnder interferometer
10.	Determination of the refractive index profile of a multimode and single mode fibre by the transmitted near field scanning technique and measurement of NA.
11.	Measurement of attenuation and dispersion in optical fibres
12.	WDM Mux, Demux and add drop multiplexing
13.	Fibre amplifier
14.	Particle nature of photons
15.	Quantum random number generation

COURSE OUTCOMES:

CO-1	Understanding and Hands on experience on optical elements and Fibers.
CO-2	Construction of various optical interferometers
CO-3	Introduction to Quantum phenomena.

QT 606: QUANTUM COMMUNICATIONS

SYLLABUS:

Prerequisite: Quantum Information Theory

Unit	Syllabus Details
Unit I	Elements of classical cryptography (basic understanding), RSA public and private key distribution, Block ciphers, American encryption standards (AES), Authentication and Wegman-Carter protocol, Universal hashing techniques
Unit II	Shannon and Reni entropy, BB84 protocol, Difference between free- space and fibre-based QKD systems, Quantum teleportation and swapping, Post-

	processing of QKD data, Error correction and cascade protocol
Unit III	Attack strategies on QKD protocols, QKD systems, Plug and play systems, Differential phase shift key (DPS), Time bin qubits & phase based techniques, The decoy state protocol, Measurement device independent QKD
Unit IV	Current trends in free-space and satellite QKD, QKD networks, Basic techniques of quantum optics and quantum technology
Unit V	Hands on QKD sub systems, Practical implementation of QKD system

References

1. Nielsen, Michael A.; Chuang, Isaac L., Quantum Computation and Quantum Information Cambridge: Cambridge University Press, 2012
2. Benenti, Casati, Strini, Principles of quantum computation and Information, World Scientific
3. Research papers/Articles as required

COURSE OUTCOMES:

CO-1	Explain the principles of classical cryptography (e.g., RSA, AES, universal hashing) and foundational quantum cryptographic protocols such as BB84 and quantum teleportation.
CO-2	Apply quantum key distribution (QKD) protocols like BB84, decoy state, and DPS, and describe post-processing methods including error correction and the cascade protocol.
CO-3	Analyze vulnerabilities in QKD protocols and evaluate countermeasures through measurement-device-independent (MDI) QKD and plug-and-play systems.
CO-4	Evaluate current trends in QKD systems including satellite-based and free-space QKD networks, and interpret quantum optical techniques relevant to quantum information technologies.

QT 607: QUANTUM COMPUTING II

SYLLABUS:

Prerequisite: Quantum computing I

Unit	Syllabus Details
Unit I	Quantum noise and error correction codes: Noise and the Di-vincenzo criteria. The classical error correction model. The classical three bit code. Quantum error correction. Three and nine bitcodes and the stabilizer codes.
Unit II	Quantum computing with Qiskit: Qubits; multi-qubits systems. Quantum operation on a multi-qubit system, Reversible Gates; Quantum Gates;
Unit III	Implementation of Quantum Algorithms with Qiskit: Quantum Parallelism, Phase kick-back, Deutsch's problem, Deutsch-Jozsa algorithm, Quantum Fourier transform, Quantum Phase estimation, Grover's search algorithm, Simon's problem, Shor's algorithm.

Unit IV	Physical realization of qubits: introduction to Super conducting qubits and ion traps models, Linear optical quantum computing, Single qubit gates, Computational complexities: brief introduction, models, How to compute quantum volume using free-accessible quantum sources from IBM.

Reference Books

1. Michael A. Nielsen and Isaac L. Chuang, Quantum computation and quantum information, Cambridge University Press 2010
2. Thomas H. Cormen Charles E. Leiserson Ronald L. Rivest Clifford Stein, Introduction to Algorithms, Second Edition, The MIT Press, Cambridge, Massachusetts

Reference papers

1. Robert S. Smith, Michael J. Curtis, William J. Zeng. A Practical Quantum Instruction Set Architecture. arXiv:1608.03355. 2016.
2. Eric C. Peterson, Gavin E. Crooks, Robert S. Smith. Fixed-Depth Two-Qubit Circuits and the Monodromy Polytope. arXiv:1904.10541. 2019.
3. Robert S. Smith. Someone Shouts $|01000\rangle$ Who's Excited?. arXiv:1711.02086.2017.
4. Christopher M. Dawson, Michael A. Nielson. The Solovay–Kitaev Algorithm. Quantum Information and Computation. 2005.
5. Vivek V. Shende, Igor L. Markov. On the CNOT-cost of TOFFOLI gates. Quantum Information and Computation. 2009.
6. Vivek V. Shende, Stephen S. Bullock, Igor L. Markov. Synthesis of Quantum Logic Circuits. IEEE Transactions on Computer-Aided Design, vol. 25, no. 6. 2006.

COURSE OUTCOMES:

CO-1	Explain quantum noise models, DiVincenzo criteria, and the fundamentals of classical and quantum error correction including stabilizer codes.
CO-2	Apply quantum logic gates, reversible gates, and basic Qiskit operations to simulate multi-qubit systems and error-correcting codes.
CO-3	Implement and analyze key quantum algorithms (e.g., Deutsch-Jozsa, Grover's, Simon's, Shor's) using Qiskit for real-time execution and simulation.
CO-4	Evaluate different physical models for quantum computation (e.g., superconducting qubits, ion traps, photonic systems) and assess quantum volume using IBM tools.

QT 611: QUANTUM TECHNOLOGY LABORATORY-II

SYLLABUS:

Sl. No.	Name of experiments
01.	Tomographic single photon state reconstruction
02.	Demonstration of wave nature of photons
03.	Setting up Quantum eraser system
04.	Test of wave particle dualism

05.	Visible light interference
06.	Measurement of wavelength of single photons
07.	Coherence length measurement of single photons
08.	Interaction-free measurement
09.	Test of Bell's inequality (CHSH) violation
10.	Non-classical polarization correlations
11.	Tomographic state reconstruction
12.	Demonstration of QKD (BBM protocol)
13.	Ekert protocol – test
14.	Hong-Ou-Mandel two-photon interferometers
15.	Hong-Ou-Mandel interference + Hanbury-Brown & Twiss interference FPGA based electronics and post-processing protocols for QKD

COURSE OUTCOMES:

CO-1	Demonstration of heralded single photon and the entangled photons sources.
CO-2	Construction of various single photon interferometers for the understanding of foundations of quantum mechanics.
CO-3	Hands-on experience on the characterization of single and entangled photon sources.
CO-4	Demonstration of QKD protocols using entangled photon set up.

QT 621: CLASSICAL AND POST QUANTUM CRYPTOGRAPHY

SYLLABUS:

Unit	Syllabus Details
Unit I	Introduction to Post Quantum Cryptography: What Is Post-Quantum Cryptography? Comparison to Quantum Cryptography. Introduction to Mathematics of Cryptography. Classical Cryptography.
Unit II	Hash Based Digital Signature Schemes: Hash Based One-Time Signature Schemes, Merkle's Tree Authentication Scheme, One-Time Key-Pair Generation Using an PRNG, Authentication Path Computation, Tree Chaining, Security In Merkle Signature Scheme.
Unit III	Code-Based Cryptography: Introduction to Code-Based Cryptography, Codes and Structures, McEliece Cryptosystem.
Unit IV	Lattice Based Cryptography: Introduction, Preliminaries of Linear Algebra, Finding Short Vectors, Public Key Encryption Schemes, Digital Signature Schemes, Other Cryptographic Primitives.
Unit V	Multivariate Public Key Cryptography: Introduction, the Basics of Multivariate PKCS, Examples of Multivariate PKCS, Basic Construction and Variations.

Text Book

1. Post-Quantum Cryptography by Daniel J. Bernstein, Johannes, Buchmann, Erik Dahmen, Springer. ISBN: 978-3-540-88701-0.

Reference Books/Papers

1. Regev, O. 2009. School of Computer Science Tel Aviv University. Lattices in Computer Science 0368.4282. Lectures- 1, 2, 6.5.
2. Schneier, B. 1996. Applied Cryptography. John Wiley & Sons, Inc. ISBN: 0471128457
3. Research papers/Articles as required

COURSE OUTCOMES:

CO-1	Explain the fundamental differences between classical, quantum, and post-quantum cryptographic paradigms.
CO-2	Analyze mathematical foundations essential to post-quantum cryptographic schemes.
CO-3	Apply post-quantum cryptographic algorithms such as hash-based, code-based, lattice-based, and multivariate public key cryptosystems.
CO-4	Evaluate the security and efficiency of various post-quantum cryptographic schemes for practical deployment.

QT 622: NONLINEAR OPTICS

Prerequisite: Introduction to Optics and Photonics

SYLLABUS:

Unit	Syllabus Details
Unit I	Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients. Second harmonic generation
Unit II	Phase matching condition, Various phase matching techniques, Periodically poled materials and their applications in non-linear optical devices, Sum and difference frequency generation, Optical parametric amplification (OPA) and oscillation (OPO)
Unit III	Third harmonic generation, four wave mixing and Self phase-modulation Optical Kerr effect, Self-focusing, Optical bistability, Stimulated Raman Scattering and Stimulated Brillouin Scattering, Introduction to ultrashort pulses, Ultrashort pulse generation through mode-locking, Supercontinuum generation

Text/References

1. R. W. Boyd, Nonlinear Optics, Academic Press, 2008
2. Peter E. Powers, Fundamentals of Nonlinear Optics, CRC Press, 2011.

COURSE OUTCOMES:

CO-1	Explain the principles of harmonic oscillator models, nonlinear polarization, and nonlinear wave propagation in dielectric media.
CO-2	Analyze the phase matching conditions and nonlinear frequency mixing processes such as second harmonic generation, sum/difference frequency generation, and OPA/OPO.
CO-3	Apply nonlinear optical concepts to model and interpret phenomena such as third harmonic generation, four-wave mixing, and optical Kerr effect.
CO-4	Evaluate ultrafast optical phenomena including ultrashort pulse generation, supercontinuum generation, and nonlinear scattering processes for photonic applications.

QT 623: QUANTUM METROLOGY AND SENSING

Prerequisite: Introduction to Optics and Photonics and Quantum Mechanics

SYLLABUS:

Unit	Syllabus Details
Unit I	Time dependent perturbation theory, applications like fine structure constant, hyper-fine splitting, Zeeman effect, Introduction to atom-light interactions, Rabi model, Optical cavities, Introduction to laser and their applications to metrology
Unit II	Fisher information, Cramer-Rao bound (classical and quantum), Standard quantum limit (shot-noise limit) and Heisenberg limit (squeezed light), Ghost imaging (quantum enhanced imaging), Quantum illumination, Quantum reading, Quantum RADAR, Super-resolution with OAM beams and vector beams
Unit III	Cold atoms, Gravimeters and time-stamping based on atom interferometry, Josephson junction and NV color centers in diamonds for sensing, Lock-in detection, spectroscopy, Doppler-limit and Doppler-free spectroscopy
Unit IV	Frequency standards, Frequency combs, atomic clocks, SQUID techniques
Unit V	Hands-on Quantum sensing experiment

Textbook/ References

1. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, 2nd ed..John Wiley, 2007
2. A. Yariv, Quantum Electronics, John Wiley.
3. Research papers/Articles as required

COURSE OUTCOMES:

CO-1	Explain time-dependent perturbation theory and atom-light interactions, including models like Rabi oscillations and optical cavities, with applications in spectroscopy and lasers.
CO-2	Apply concepts of quantum limits, Fisher information, and the Cramer-Rao bound to evaluate quantum-enhanced measurement techniques.
CO-3	Analyze quantum sensing schemes such as ghost imaging, quantum illumination, quantum radar, and super-resolution using structured light.
CO-4	Evaluate cold atom-based sensors, atomic clocks, SQUIDs, and frequency combs for high-precision quantum metrology and sensing applications.

QT 624: QUANTUM OPTICS**Prerequisite: Introduction to Optics and Photonics and Quantum Mechanics****SYLLABUS:**

Unit	Syllabus Details
Unit I	Field quantization, Correlation functions, photon statistics, shot noise of the photodetectors, Poissonian and sub-Poissonian light, Photon bunching and antibunching, HBT experiment
Unit II	single photon sources, Coherent states and squeezed states, Phasor diagram, generation and detection of squeezed light, Quantum noise, Phase space representation and Wigner function.

Text/References

1. Mark Fox, Quantum Optics: An Introduction, Oxford master series in physics, 2007
2. A guide to experiments in Quantum Optics, Hans-A Bachor, T. C. Ralph, 3rd edition, Wiley, 2019

COURSE OUTCOMES:

CO-1	Explain the principles of field quantization, correlation functions, and photon statistics, including phenomena such as photon bunching and antibunching.
CO-2	Analyze non-classical light sources such as single-photon and squeezed light, and interpret their statistical properties using phase-space methods like Wigner functions.

CO-3	Apply quantum optical models to study photodetection noise characteristics, generation and detection techniques of squeezed states, and coherence properties of light.

School of Defence Technology & Management

M.Tech. in Technology Management

PSC: Program Specific Core

PE: Professional Elective

Semester I

Sl. No.	Course Type	Course Code	Course	Contact Hours/week			Credits
				L	T	P	
1	PSC-1	TM601	Introduction to Technology Management	3	0	0	3
2	PSC-2	TM602	R&D and Innovation Management	3	0	0	3
3	PSC-3	TM603	Project Management	3	0	0	3
4	PSC-4	TM604	Strategic Management for Technology	3	0	0	3
5	PE-1		Elective -I	2	1	0	3
6	PSC	TM605	Data Analysis for Managers - I	3	0	0	3
7	PGC	PGC-601	Research Methodology & IPR	2	0	0	2
			Total	19	1	0	20

Semester II

Sl. No.	Course Type	Course Code	Course	Contact Hours/week			Credits
				L	T	P	
1	PSC-5	TM610	Leadership & Organisational Behaviour	3	0	0	3
2	PSC-6	TM612	Total Quality Management	3	0	0	3
3	PE-II		Elective -II	3	0	0	3
4	PE-III		Elective -III	3	0	0	3
5	PE-IV		Elective -IV	3	0	0	3
6	PSC	TM622	Data Analysis for Managers - II	2	1	0	3
7	PGC	PGC-602	Personality Development & Communication skills	2	0	0	2
			Total	19	1	0	20

Semester III

			Course	Contact Hours /week	Credits

Sl. No.	Course Type	Course Code		L	T	P	
1	Dissertation & Seminar Phase 1	TM651	M.Tech. Dissertation Phase I				20
			Total				20

Semester IV

Sl. N o.	Course Type	Course Code	Course	Contact Hours /week			Credits
				L	T	P	
1	Dissertation & Seminar Phase 2	TM652	M.Tech. Dissertation Phase II				20
			Total				20

LIST OF ELECTIVES (Elective I, II, III, IV)

Sl. No.	Course Code	Course Name
ELECTIVES FROM DEPARTMENT		
Semester 1		
1	TM615	Developing Human Capital in Technology-Intensive Organizations
Semester 2		
1	TM607	Management of Manufacturing and Integration
2	TM608	Knowledge Management
3	TM609	System Engineering for Managers
4	TM611	Software Projects Management
5	TM613	Value Engineering
6	TM614	Design Management
7	TM616	Introduction to variables of Nation Building
8	TM617	Logistics and Supply Chain Management
9	TM618	Operations Management
10	TM619	Advanced Project Management Techniques
11	TM620	Accounting and Finance for Technologists
12	TM621	Artificial Intelligence (AI) in Management
NPTEL/SWAYAM COURSES		

Semester 1		
1		Management of Human Resource
2		HRM for Non-HR Managers
3		Organisation of Engineering Systems and Human Resources Management
4		HR Analytics
Semester 2		
1		AI in Human Resource Management
2		AI in Product Management
3		Supply Chain Digitization
4		Modelling and Analytics for Supply Chain Management
5		Quality Design and Control
* 1 Credit in Theory/Tutorial means 1 contact hour * 1 Credit in practice/Project Thesis means 2 contact hours in a week * Maximum of 6 Credits can be opted by students as Professional Electives (Approved by BoS) from the list of Online Courses on NPTEL / SWAYAM during I & II Semester.		

Program Outcomes (POs)

PO1: To develop an ability to identify, understand, analyze the management issues in an organization.

PO2: To be able to perform statistical research for better management solutions.

PO3: To achieve excellence in management decisions and give managerial as well as academic interpretations based on management by facts.

Program Specific Outcomes (PSOs)

PSO1: To learn the basics and advances in Technology Management perspective and overcome the time & cost overruns of various defence related projects.

PSO2: To utilize the human resources and their intellectual abilities for betterment in projects, R&D and strategy formulation.

PSO3: To analyse management cases through problem solving approach inclined to corporate decisions.

Course Code	Course Name	L – T – P	Credits

TM601	INTRODUCTION TO TECHNOLOGY MANAGEMENT	3-0-0	3
Course Objectives: • To provide students with a comprehensive understanding of the strategic role and evolution of technology in modern organizations. • To manage technology resources effectively, integrate technological innovations, and leverage technology for competitive advantage. • Key topics include technology life cycle, technology strategy, technology forecasting, product development and the impact of emerging technologies on business processes. • To develop and implement technology management strategies that align with organizational goals, drive innovation, and enhance operational efficiency.			
Course Contents Unit I Introduction to technology, History of managing tech in India, Managing in today's high tech environment and mgmt. Tech – scope and focus, The Role of Technology in the Creation of Wealth, Critical Factors In Managing Technology, Management of Technology: The New Paradigms, Technology Life Cycles, Tech life cycle and product life cycles, Tech maturation and tech substitution, Integrating tech and strategic planning, Core competencies for tech development Unit II Understanding the Dynamics of Technology & Product development Environment, Technology Search Mechanisms, Technology Assessment Models, Technology selection criteria, In-sourcing & Out-sourcing decisions in Technology development, Competitiveness, Business Strategy and Technology Strategy Unit III Technology Planning, Acquisition and Exploitation of Technology, Managing risk in high technology, Transfer of tech from lab to land. Technology Transfer, Manufacturing and Service Industries, Design of Organizations, Changing Game of Management, Case Studies (How the World Does It).			
Course Outcomes			
After completing this course, the students will be able to: CO1: To understand the issue around Technology management, Technology Cycle and wealth creation through technological development. CO2: To identify the technology decisions for push-pull, assessments, strategy. CO3: To evaluate the process of Technology planning, forecasting, road-mapping, transfer, acquisition, exploitation. CO4: To analyze Key current technological issues for organizations sustenance and transferring technology lab to land.			
Text Books			

1. Tareek Khalil and Ravi Shankar, Management of Technology: the key to Competitiveness and Wealth Creation, Second Edition, McGraw-Hill Publishing Company Ltd, New Delhi (2012). 2. Thahaman H.J., Management of Technology, New Jersey: John Wiley & Sons, 2005. 3. Bringing Technology and Innovation into the Boardroom: Strategy, Innovation and Competences for Business Value Thomas Durand, Ove Granstand, Cornelius Herstatt, Arie Nagel, David Probert, Breffni Tomlin and Hugo Tschirky 4. Roadmapping for Strategy and Innovation - Aligning technology and markets in a dynamic world (Phaal, R; Probert, D; Farrukh, C.) ISBN 978-1-902546-82-7 5. Management of Technology and Innovation Competing Through Technological Excellence , Second Edition P N Rastogi , Sage publications 6.
Reference Books
1. BETZ Frederick, Strategic Technology Management, New York: McGraw Hill, 1994. 2. Steele, Lowell W. Managing technology: the strategic view. New York: McGraw-Hill, 1989. 3. Turn the Ship Around!: A True Story of Turning Followers into Leaders (Hardcover) by L. David Marquet 4. Technopoly: The Surrender of Culture to Technology by Neil Postman

Course Code	Course Name	L – T – P	Credits
TM602	R&D AND INNOVATION MANAGEMENT	3-0-0	3
Course Objectives: • To impart knowledge on the significance and structure of R&D in the technology sector. • To differentiate between types of research and develop strategic plans for effective R&D management. • To familiarize students with various innovation types and models, and the process of managing technological innovation. • To align human resource strategies with R&D goals, fostering a creative and collaborative culture while managing intellectual property rights.			
Course Contents Unit I <i>Foundations of R&D Management</i> - Definition and significance of R&D in the technology sector, R&D Categories and Organizational Structures- Differentiating between basic research, applied research, and development, Organizational structures for effective R&D management, Technology Road mapping and Planning - Strategic planning for R&D in technology management, Creating technology roadmaps, Aligning R&D goals with organizational objectives, Funding and Resource Allocation in R&D - Sources of funding for R&D projects, Budgeting, and resource allocation strategies. Unit II			

<i>Technology Innovation Management</i> - Definition and types of innovation, Innovation models, Steps of innovation management, technological innovation process, technology innovation management planning, technological innovation management strategies, technology forecasting and Incubators Unit III <i>Human Resource & Intellectual Property Management</i>- Aligning HR Strategy with R&D Goals, Fostering a Creative Culture in R&D, Team Dynamics and Building Collaborative R&D Teams, Designing Effective Reward Systems, Performance Appraisal and Career Management in R&D, Creation of IPR, types of IPR, Patents and Copyrights in India
Course Outcomes After completing this course, the students will be able to: CO1: Analyze organizational structures to optimize R&D management, aligning goals with organizational objectives and efficiently managing funding sources for project success. CO2: Define and categorize innovation types; grasp innovation management steps and processes, devising effective technology innovation strategies. CO3: Align human resource strategies with R&D objectives, fostering a culture of creativity and collaboration and navigate intellectual property rights intricacies, focusing on Indian context for comprehensive R&D management.
Text Books 1. Melissa A Schilling & Ravi Shankar, Strategic Management of Technological Innovation, McGraw Hill, 2021. 2. Hawthorne E.P., Management of Technology, McGraw-Hill, 1978. 3. Akhilesh KB, R&D Management, Springer, 2013 4. Trott, P., Innovation Management and New Product Development, Financial Times, Pitman Publishing, GB, 1998. 5. The Reflective Practitioner D.A. Schone Basic Books, NY, 1982 6. Anurag K. Agarwal, Business And Intellectual Property, Penguin Random House 7. Dr. Mathew Thomas, Understanding Intellectual Property, Eastern book company
Reference Books Reference Books: 1. Beattle C.J. & Reader R.D., Quantitative Management in R&D, Chapman and Hall, 1971. 2. Gibson J.E., Managing Research and Development, Wiley & Sons Inc., New York, 1983 3. Vittorio Chiesa, R&D Strategy and Organisation Managing Technical Change in Dynamic Contexts, Imperial College Press 4. Joe Tidd & John R. Bessant, Managing Innovation: Integrating Technological, Market and Organizational Change, 7th Edition, Wiley 5. Shlomo Maital, Innovation Management: Strategies, Concepts and Tools for Growth and Profit, Sage Publishers 6. Genrich Altshuller, Lev Shulyak : And Suddenly the Inventor Appeared: TRIZ: Theory of Inventive Problem Solving

Course Code	Course Name	L – T – P	Credits
TM603	PROJECT MANAGEMENT	3-0-0	3
Course Objectives: • To equip students with the essential knowledge and skills required to successfully initiate, plan, execute, control, and close projects. • To learn about project management methodologies, tools, and best practices. Key topics include project scope, time, cost, quality, risk management, stakeholder engagement, and team dynamics. • To apply project management principles to deliver projects on time, within budget, and to the specified quality standards.			
Course Contents Unit I Project Management Foundation: Need for Project Management benchmark, Project, Programme, Portfolio, Product & Project lifecycle, Project Management Success Organization: The Strategy, Governance, structures, processes, Compliance, standards, regulations, Power & interest, Culture & values, Scope Management: Requirements (Functional, Non-functional), Product Scope, Project Scope, Work Breakdown Structure and its types, Scope Creep & Gold Plating, Configuration Management. Unit II Schedule Management : Project Network Diagram (Activity on Node diagram), Estimation, Critical Path Method & Network analysis, Schedule compression (Crashing, Fast tracking), Resource histogram, smoothing, leveling, Cost Management: Formulating Project Budget & S Curve, Contingency & Management reserve, Chart of Accounts & Cost breakdown structure, Direct & Indirect cost, Earned Value Management (EVM), Quantitative Project Performance Measurement, Forecasting Budget & Project duration, Application of EVM for uniform and un-uniform work Unit III Risk & Opportunity Management : Risk identification & aiding tools, Qualitative & Quantitative Risk Analysis, Strategies for addressing negative & Positive risks, Risk Response Planning, Residual Risk & Risk control, Procurement Management: Contract & Purchase order, Steps in Procurement, Types of Contract, Supplier management, Quality Management: Quality concepts, Quality Planning, Assurance & Control, Cost of Quality, Quality tools Unit IV Resource Management: Resource Planning, Project Organization, Responsibility assignment Matrix, Project Communication, Monitoring & Control, Change Management, Milestone trend chart, People Competencies, Self-reflection & self-management, Personal integrity & reliability, Personal communication, Relationships and engagement, Leadership & Teamwork, Conflict and crisis			

Course Outcomes			
After completing this course, the students will be able to: CO1: To recognize key factors in projects and project stages, cycle and responsibilities.. CO2: To identify risk associated with project, its dynamics and team requirements for successfulness. CO3: To align the project activities through project network techniques and scheduling and its cost-time tradeoffs. CO4: Assessing the budget allocation/ financing issues, project handling and implementations through various case studies			
Text Books			
1. Iyer, P.P., Engineering Project Management with Case Studies, Vikas Publishing, New Delhi, 2009. 2. J.R.,Merreddith and Samuel J.Mantel, Jr., Project Management: A Managerial Approach, John Wiley and Sons, NY, 8th Edition. 3. P Gopalakrishnan & V E Ramamoorthy, Textbook of Project Management, Trinity Press			
Reference Books			
1. John M. Nicholas and Herman Steyn, Project Management for Business, Engineering, and Technology: Principles and Practices (Third Edition), Elsevier (2008). 2. Clifford F. Gray, Erik W. Larson and Rohit Joshi, Project management: The Managerial Process (7th Edition), Mc Graw Hill Education (2023). 3. Project Management Institute, USA. A Guide to the Project Management Body of Knowledge. Newton Square, (7th Edition),PA. 2021. 4. Project Management Absolute Beginner's Guide ,Author: Greg Horine 5. Project Management for Non-Project Managers , Jack Ferraro 6. Project Management Case Studies , Harold Kerzner 7. Making Things Happen: Mastering Project Management, Scott Berkun 8. The Lazy Project Manager: How To Be Twice As Productive And Still Leave The Office Early , Peter Taylor			

Course Code	Course Name	L – T – P	Credits
TM604	STRATEGIC MANAGEMENT FOR TECHNOLOGY	3-0-0	3
Course Objectives: • <i>To analyze Industry and Environmental Dynamics</i> : Enable students to analyze industry structures, assess external and internal environments, and recognize opportunities for technological innovation and disruption			

• To formulate and Implement Technology Strategies : Teach students to formulate effective technology strategies, including setting vision and mission, establishing objectives, and crafting strategies for technology-driven organizations • To prepare for Emerging Trends and Global Challenges : Equip students to anticipate and respond to emerging trends, global competition, and sustainability challenges in technology management • Foster Entrepreneurial and Critical Thinking: Encourage entrepreneurial thinking, critical analysis, and the mitigation of biases in technology management decisions
Course Contents Unit I : Introduction to Strategic Management of Technology : Strategic Management Process; Challenge of Globalization; Strategic Planning in India; Corporate Governance; Board of Directors; Role and functions of Top Management. Unit II: Industry and Environmental Analysis: Analyzing industry structure for technology opportunities, Understanding market failures and disruptions, Forecasting technological change. Unit III: Technology Strategy Formulation: Situation Analysis and Business Strategy, Corporate Strategy, Functional Strategy, Strategy Implementation and Control, Strategic Alternatives; Diversification, Mergers and Acquisitions. Unit IV: Case Studies and Practical Applications: Real-world examples from various sectors, Group assignments and presentations.
Course Outcomes After completing this course, the students will be able to: CO1: Describe the practical and integrative model of strategic management process that defines basic activities in strategic management CO2: Demonstrate the knowledge and abilities in formulating strategies and strategic plans CO3: Analyze the competitive situation and strategic dilemma in dealing with global business environment and technological advancement CO4: Evaluate challenges faced by managers in implementing and evaluating strategies based on the nature of business, industry, and cultural differences
Text Books 1. R. Srinivasan, Strategic Management – The Indian Context, Prentice-Hall of India, 3rd Edition, 2008 2. Burgelman, Christensen, and Wheelwright Strategic Management of Technology and Innovation by, TMH 3. David Baker, The Strategic Management of Technology, Woodhead Publishing Limited. 4. Edward B. Roberts, Strategic Management of Technology: Global Benchmarking, Leopold Classic Library 5. Melissa A Schilling & Ravi Shankar, Strategic Management of Technological Innovation, McGraw Hill, 2021.
Reference Books 1. Azhar Kazmi, Business Policy and Strategic Management, 2e. Tata McGraw Hill Education. 2. R. Srinivasan, Case Studies in Marketing – The Indian Context, Prentice-Hall of India, 4th Edition, 2002

3. Frederick Betz, Strategic Technology Management, McGraw-Hill Inc., US 4. Pierre Dussauge, Stuart Hart, Bernard Ramanantsoa, Strategic Technology Management, Wiley			
Course Code	Course Name	L – T – P	Credits
TM605	DATA ANALYSIS FOR MANAGERS - I	2-1--0	3
Course Objectives: - To introduce students to the fundamental concepts and importance of statistics in management decision-making. - To equip students with the ability to analyze and interpret different types of data, using measures of central tendency and variability. - To develop students' skills in constructing and analyzing frequency distributions and understanding basic probability concepts. - To enable students to apply statistical tools to real-world management problems and make data-driven decisions.			
Course Contents Unit I Introduction to Statistics and Descriptive Statistics-Definition and importance of statistics in management, Types of data: qualitative and quantitative, Role of statistics in decision-making, Measures of central tendency: mean, median, mode, Measures of variability: range, variance, standard deviation. Frequency distributions and histograms. Basic concepts of probability - Probability distributions and rules of probability. Unit II Inferential Statistics- Sampling theory, Sampling distributions and the Central Limit Theorem, Confidence Intervals, Hypothesis testing - Null and alternative hypotheses, Type I and Type II errors, Z-test and t-test for Paired and independent samples hypothesis testing Unit III Application of descriptive and inferential statistics in technology management problems - Case studies & Problem-solving using statistical tools-Minitab, SPSS & R.			
Course Outcomes			
After completing this course, the students will be able to: CO1: Grasp the significance of statistics in management; distinguish between qualitative and quantitative data for informed decision-making. CO2: Apply inferential statistics principles, including sampling theory and the Central Limit Theorem, for accurate decision-making. CO3: Utilize statistical tools like Minitab, SPSS, and R in real-world scenarios, developing practical skills to enhance managerial decision-making processes through data-driven insights.			
Texts Books:			
1. Morrison J. Statistics for engineers: An introduction. John Wiley & Sons; 2009 Jul 20.			

Reference Books
1. Keller, Gerald, and Brian Warrack. Statistics for management and economics. Vol. 1. South Western Educational Publishing, 2004.

Course Code	Course Name	L – T – P	Credits
TM615	DEVELOPING HUMAN CAPITAL IN TECHNOLOGY-INTENSIVE ORGANIZATIONS	3-0-0	3

Course Objectives:

- To acquaint students with the techniques and Principles to manage human resource of an organization in dynamic environments.
- To provide an understanding of the Sustainable competitive advantage through Human Resources.
- To focus on management best practices, tools and models to implement an effective HRD system.
- To build advanced analytics skills and managerial judgment to collect, analyse and interpret data effectively.

Course Contents

Unit I

Nature and Scope of HRM, Personnel Management & HRM, elements & model, functions, challenges, *Balanced Scorecard* - History, perspectives, BSC & Strategy, *Competency Management* - Concept, need, competence & competency framework.

Unit II

Cross Cultural Management Nature, Hofstede's cultural dimensions, strategy; *HR Audit*- need, concept, strategy, structure, Role of HRD audit, functions, methodology; *Human Capital Management*: elements, significance, measurement, reporting.

Unit III

Management of change - The nature of change, Eight steps to successful change, Change management and organizational structure, Change strategies, Change resistance, *Effective communication*, *Effective leadership*, *Emotional Intelligence*.

Unit IV

HR Analytics - Introduction, HR Analytics issues and metrics, Data Preparation, Data summarization and visualization of HR data, Exploratory Data Analysis with HR data, Modelling, clustering, affinity analysis, predictive analysis, prescriptive analysis, AI/ML of HR processes and practices.

Course Outcomes

After completing this course, the students will be able to :

CO1: Critically assess existing theory and practice in the field of HRM and develop an ability to undertake qualitative and quantitative research

CO2: Identify and apply new ideas, methods and ways of thinking, Demonstrate competence in communicating and exchanging ideas in a group context

CO3: Work effectively with colleagues with diverse skills, experience levels and way of thinking CO4: Develop leadership for high-performing analytics teams and implement analytics-driven organisational change.
Text Books
1. Aswathappa, Human Resource Management: Text and Cases, 10th Edition, McGraw Hill, 2023. 2. V. S. P. Rao, Human Resource Management, 3rd Edition, Taymann Pub, 2023. 3. Palmer et al. (2009): Managing Organizational Change: A Multiple Perspectives Approach, McGraw-Hill – 4. Bridges (2009): Managing Transitions: Making the Most of Change, Da Capo Press
Reference Books
1. Gary Dessler, Human Resource Management 12 Edition (Old Edition), 2011. 2. Dessler/Varkkey, Human Resource Management 14e(4 Color), Pearson, 2015 3. P. Jyothi & D.N. Venkatesh, Human Resource Management (Oxford Higher Education), 2012. 4. Kotter (1996): Leading Change, Harvard Business School Press 5. Linstead et al. (2009): Management and Organization: A Critical Text, Palgrave

Course Code	Course Name	L – T – P	Credits
TM610	LEADERSHIP & ORGANISATIONAL BEHAVIOUR	3-0-0	3
Course Objectives: • Understanding organisations Building cultures • Motivating people • Interpersonal communication • Working in teams Leading and managing change • To increase participants' knowledge of "EQ" and to improve their interpersonal and intra-personal skills.			
Course Contents Unit I Introduction to Organizational Behaviour, definition, importance, scope, fundamental concepts of OB, different models of OB: Autocratic, custodian, supportive, collegial, SOBC. Unit II Personality, Perception, Learning, Attitudes, Emotions, Motivation, Interpersonal Behaviour at Work, Communication Unit III Organizational culture, Decision Making, Group Dynamics, Teams and conflict management, Organizational Structure, Organizational Change Unit IV			

Fundamentals of Leadership, Leadership, Contingency leadership theories, The art of influencing in leadership
Course Outcomes
After completing this course, the students will be able to: CO1: Describe the field of organizational behavior and discuss its relevance to the workplace. CO2: Identify and evaluate the components of individual behaviour in organizations and apply these concepts to real-world situations CO3: Analyze group dynamics, team development, and the behaviour of individuals in teams; demonstrate skills required for effective teamwork and team leadership CO4: Assess the factors influencing organizational behaviour at both individual and group levels CO5: Develop and demonstrate interpersonal and leadership skills necessary for managing people and fostering a positive organizational climate
Text Books
1. Paul Hersey, Kenneth H Blanchard & Dewey Johnson, Management of Organisational Behavior PHI 2. John W Newstrom & Keith Davis, Organizational Behavior: Human Behavior at work, Tata McGraw Hill 3. Fred Luthans, Organizational Behavior, McGraw Hill 4. K. Aswathappa, Organisational Behavior 5. Newstrom, J. W, Organizational Behavior: Human Behavior At Work.TMH 6. Sekaran, Uma, Organisational Behaviour: Text & Cases TMH 7. Aswathappa, K, Organisational Behaviour: Text, Cases, Games. Himalaya
Reference Books
1. Paul Hersey & Kenneth H Blanchard, Management of Organisational Behavior: utilizing Human Behaviour, PHI 2. Stephen P Robbins, Organizational Behavior: Concepts, controversies and applications, PHI

Course Code	Course Name	L – T – P	Credits
TM612	TOTAL QUALITY MANAGEMENT	3-0-0	3
Course Objectives: • The objective of this course is to enhance knowledge of students with a thorough understanding of quality management concepts, principles, and practices. • Students will explore various quality management systems, tools, and techniques essential for ensuring product and service excellence. • Key topics include QM philosophies, Total Quality Management (TQM), Six Sigma, statistical process control, quality improvement methodologies, and quality assurance for manufacturing and service organizations.			

- By the end of the course, students will be capable of implementing quality management strategies to enhance organizational performance, customer satisfaction, and continuous improvement in diverse business environments.

Course Contents

Unit I

Introduction to TQM and Six Sigma: Customer Orientation, Continuous Improvement, Quality, Productivity and Flexibility, Approaches and philosophies of TQM, Quality Awards, Strategic Quality Management, TQM and corporate culture, Total Quality Control; Quality Costs, Basic Analytical tools-Check Sheets; Histograms; Pareto charts, Cause and Effect diagrams; Flow charts, Quality assurance, OC curve

Unit II

Statistical Process Control; Advanced Analytical tools: Statistical Design of Experiments; Taguchi Approach; Cost of Quality; Reliability and failure analysis. FMEA, Six Sigma tools and techniques for DMAIC phases, Quality Function Deployment, Tolerance stack up analysis.

Unit III

Quality Teams, Employee practices in TQM organisations: Leadership, delegation; empowerment and motivation; role of communication in Total Quality, Quality Circles; Total Employee Involvement; Problem Solving in TQM- Brain storming; Nominal Group Technique Team process; Kaizen and Innovation; Measurement and audit for TQM; Quality Information Systems, ISO 9000 series of Quality Standards; TQM and Six Sigma case studies implementation.

Course Outcomes

After completing this course, the students will be able to:

CO1: To learn quality related issue and quality philosophies

CO2: Usefulness of tools and techniques of seven quality control

CO3: Application of Quality six sigma approach with DMAIC phases, FMEA and QFD for benchmarking.

CO4: Strategies for achieving incremental quality process through innovative problem solving approach and maintaining quality standards.

Text Books

1. O.N. Pandey Bhupesh Aneja, Quality Management, Katson Books.
2. Besterfield, Total Quality Management, 4th edition, Pearson.
3. R. Panneerselvam, p. Sivasankaran, Quality Management, PHI Publication.

Reference Books

1. James R. Evans & William M. Lindsay, Managing for Quality and Performance Excellence, Seventh Edition, Cengage learning (2008)
2. John S Oakland, TQM: Text with Cases, Taylor and Francis Culley, William C. Environmental and quality systems integration, CRC Press Company (2004)
3. V. K. Khanna, PremVrat, B. S. Sahay and Ravi Shankar (2008): Total Quality Management: Planning Design and Implementation, New Age International Publication, New Delhi.

Course Code	Course Name	L – T – P	Credits
TM622	DATA ANALYSIS FOR MANAGERS - II	2-1-0	3

Course Objectives:

- To enhance students' understanding of regression and correlation analysis for managerial decision-making.
- To develop advanced skills in hypothesis testing, including parametric and non-parametric tests, and their applications.
- To provide students with knowledge of factor analysis and time series analysis, enabling them to forecast and interpret complex data patterns.
- To prepare students to use statistical software tools for solving practical problems and making informed managerial decisions.

Course Contents

Unit I

Decision Making with Data- Regression Analysis- linear and multiple regression, Interpretation of regression coefficients. Correlation Analysis- Multiple and Partial correlations, Interpretation of correlation coefficients. Case studies and real-world examples of regression and correlation.

Unit II

Advanced Hypothesis Testing - Chi-square test, Non-parametric tests: Mann-Whitney U test, Kruskal-Wallis test, Analysis of Variance (ANOVA)- One-way ANOVA, Two-way ANOVA and Multivariate Analysis of Variance (MANOVA)

Unit III

Factor and Time Series Analysis - Factor Analysis, Time Series Components-Trends, seasonality, and cyclical patterns, Decomposition of time series data, Time Series Models averages and exponential smoothing, Autoregressive Integrated Moving Average (ARIMA) models, Forecasting Methods forecasting, and Qualitative forecasting methods. Case studies and real-world applications.

Course Outcomes

After completing this course, the students will be able to:

CO1: Apply correlation analysis methods accurately, drawing insights crucial for managerial strategies supported by real-world case studies.

CO2: Develop advanced hypothesis testing skills, including chi-square, Mann-Whitney U, and ANOVA tests, ensuring robust statistical inference for managerial decision-making.

CO3: Apply non-parametric tests effectively across diverse scenarios, enhancing the reliability of managerial insights.

CO4: Acquire a comprehensive knowledge of factor and time series analysis; understand trends, seasonality, and cyclical patterns for informed decision

Text Books

1. Levin Richard, I., Rubin David, S., Sanjay Rastogi and Masood Husain, S., Statistics for Management, Seventh Edition, Pearson Education India (2012).
2. Foster JJ, Barkus E, Yavorsky C. Understanding and using advanced statistics: A practical guide for students. Sage; 2005 Nov 29.
3. S C Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons (2014)
4. Andy Field, Discovering Statistics Using SPSS, Third Edition, Sage Publications Ltd, London (2009)

Reference Books

1. Lawson, J. and Erjavec, J., Modern Statistics for Engineering and Quality Improvement, First Edition, Duxbury Press (2000).
2. Anderson, Sweeney, Williams Camm and Cochran, Statistics for Business and Economics, Twelfth Edition, Cengage Learning (2014)

Course Code	Course Name	L – T – P	Credits
TM617	LOGISTICS AND SUPPLY CHAIN MANAGEMENT	3-0-0	3
Course Objectives: • To provide students with a comprehensive understanding of supply chain management principles and practices. • To design, analyze, and improve supply chains to enhance efficiency, sustainability, and responsiveness. • Key topics include demand forecasting, inventory management, logistics, procurement, and supply chain integration. • By the end of the course, students will be able to apply analytical tools and strategic frameworks to optimize supply chain operations.			

Course Contents

Unit I

Introduction to Logistics and supply chain management (LSCM): Concept and objectives of logistics management and supply chain management (SCM), Flow in supply chain, Decision phases in supply chain, Push-pull supply chains, Supply chain integration, Process view of a supply chain, Lead time management, Cold chains, Reverse logistics, Uncertainties in supply chain, supply chain drivers. Demand management in SCM; *Sourcing and Procurement:* Vendor development, Outsourcing benefit, Vendor evaluation and rating, supply contracts, competitive bidding and Negotiation, E-Procurement, Vendor managed inventory (VMI); *Purchasing:* Objectives, Relations with other departments, centralised and decentralised purchasing, Purchasing procedure in government organisations in India, Types of orders, Tender buying, purchasing department records, Computer-based systems/EDI, Stores management.

Unit II

Inventory Management in SCM: Introduction of inventory system, EOQ model, ABC-VED Analysis, Service-level management, Risk pooling and postponement strategies, Lean, Agile and Leagile supply chain, Designing lean supply chain; *Distribution Management in Supply Chain:* Different distribution strategies in supply chain, warehousing and cross- locking, Network planning and design, 3PL and 4PL, Circular Supply chain.

Unit III

Managing Information flow in supply chain: Bullwhip effect- cause and remedy. Role of Information technology in SCM; *Performance management in a supply chain:* Balance scorecard and SCOR Framework. Sustainable and low-carbon supply chains. Sustainable freight transportation. Supply chain risk management.

Course Outcomes

After completing this course, the students will be able to:

CO1: Understand the concept of Logistics, supply chain flows and drivers

CO2: Learn Supply chain integration and process view for supply chain strategies.

CO3: Advanced tools for managing supply chains through VMI, EDI, E-commers, centralized-decentralized process.

CO4: Outsourcing, bidding, negotiation, procurement procedures through case studies of various companies.

Text Books

1. Simchi-Levi, D., Kaminsky, P., Simchi-Levi, E., and Ravi Shankar, Designing & Managing the Supply Chain: Concepts, Strategies & Case Studies, Fourth Edition, McGraw-Hill Publishing Company Ltd, New Delhi (2023)
2. F. Robert Jacobs, Ravi Shankar, and Richard B. Chase: Operations & Supply Chain Management (17th Edition), McGraw-Hill Publishing Company Ltd, New Delhi (2024)

Reference Books	
1. Chopra, S., Meindl, P. and Kalra DV, Supply chain Management: Strategy, Planning and Operations. Sixth Edition, Pearson Education (2016)	
2. Tersine, R.J. Principles of Inventory and Materials Management, 4 th edition, Prentice-Hall Inc., New Jersey, (1994)	

ELECTIVES FROM DEPARTMENT

Course Code	Course Name	L – T – P	Credits
TM607	MANAGEMENT OF MANUFACTURING AND INTEGRATION	3-0-0	3

Course Objectives:

- Make management level decisions within a manufacturing environment to align processes with organizational, strategic and operational goals
- Use manufacturing-related software applications and quality principles to support experience- driven management decisions.
- Optimize manufacturing processes and product quality using software design integration to support operational and strategic goals.

Course Contents

Unit I

Introduction to Manufacturing, Concepts of Total Quality Management (TQM) and Six Sigma, Benchmarking and Business Process reengineering, The continuous process improvement cycle.

Unit II

Lean Manufacturing, Design for Manufacturing. Rapid Prototyping, 3D printing, IT for Manufacturing: Digital and Smart Factory, Virtual Product Creation, Interface between R&D and Manufacturing, Product Lifecycle Management, Concurrent and Simultaneous Engineering, cellular manufacturing system, design planning and implementation, Digital platforms.

Unit III

Advanced Manufacturing System: Automation of Manufacturing Processes – an overview, Flexible Automation, Integrated Manufacturing Modelling and FMS, Hardware Components, Control Components, System Planning and Design Problems, Production Planning, Process Planning, Scheduling, Economic and Technological Aspects, Automation / Mechatronics / Robotics, Industry 4.0 and Smart Manufacturing: Building blocks and integration			
Course Outcomes			
After completing this course, the students will be able to:			
CO1: To compete for the future through human resource management and organizational behavior concepts.			
CO2: To acquire knowledge of changing role of Managerial leadership leads to managing high risk in handling technology and building high performance teams.			
CO3: To understand the critical-to-quality concepts to increase overall productivity. To learn quality related issue and quality philosophies.			
CO4: To drive the economy for R&D activities through strategic aspects. To provide the strategies to mitigate cost and time overrun.			
CO5: To study the role of management of manufacturing and integration for working towards industry 4.0.			
Text Books			
1. Partik Jonsson and Stig-Arne Mattsson, “Manufacturing, planning and control”, McGraw-Hill, 2011 2. K. L. S. Sharma, “Overview of Industrial Process Automation”, Elsevier, 2011. 3. Kuldeep Sareen and Chandandeep Grewal, ”CAD/CAM”, S. Chand and Company Ltd., 2009 4. H. D. Ramachandra, “Mechatronics”, Sudha Publication, 2006			
Reference Books			
1. Michael Grieves, “Product lifecycle management”, McGraw-Hill, 2006 2. Tien-Chien Chang, Richard A. Wysk and Hsu-Pin Wang, “Computer-Aided Manufacturing”, Pearson, 2009 3. Mark W. Spong, Seth Hutchinson and M. Vidyasagar, “Robot Modelling and control”, Wiley, 2006 4. Mikell P. Groover, “Principles of modern manufacturing”, Wiley, 2014 5. Chris Anderson, “Makers: The New Industrial Revolution”, Cornerstone Digital, 2013			

Course Code	Course Name	L – T – P	Credits
TM608	KNOWLEDGE MANAGEMENT	3-0-0	3

Course Objectives:

A Knowledge Management (KM) course typically aims to equip students with a comprehensive understanding of the field's principles, practices, and strategic value. Common objectives include:

- Understand the fundamental theories, concepts, and definitions of knowledge management, including the distinction between data, information, knowledge, and wisdom
- Develop skills to implement KM strategies and frameworks, including best practices, methodologies, and tools for knowledge sharing and retention
- Assess the impact of KM on organizational performance, decision-making, and competitive advantage
- Foster an open culture that values knowledge sharing, continuous learning, and employee development
- Prepare students to apply KM concepts to real-world scenarios, including manufacturing and service industries, and to anticipate future trends in KM

Course Contents**Unit I**

Concepts of Knowledge, Knowledge Management, Knowledge Management Strategy, Knowledge Management Cycle, Capturing Tacit Knowledge

Unit II

Knowledge transfer and sharing, Design the KM Team, Legal, Ethical and Managerial issues with KM, Managing KM, Evaluation of KM effectiveness

Unit III

KM in Indian organizations, Knowledge portals, Analysis, design and development of KM system, Developing the KM system, Impact of KM, Case studies

Course Outcomes

After completing this course, the students will be able to :

CO1: Apply appropriate models of knowledge management to address learning and development needs within organizations

CO2: Distinguish between different types of knowledge (such as tacit and explicit) and apply this understanding to rectify knowledge gaps in organizations

CO3: Identify and evaluate key Knowledge Management issues, including ethics, knowledge ownership, copyright, intellectual property, and knowledge sharing incentives

CO4: Utilize current trends, tools, and techniques in Knowledge Management to attract and retain competent talent within organizations

CO5: Assess and articulate the strategic and practical implications of knowledge application at individual, group, and organizational levels

CO6: Develop and present a structured Knowledge Management strategy, including the use of key metrics to measure knowledge effectiveness.

Text Books
1. Harvard Business Review on Knowledge Management by Peter Ferdinand Drucker, David Garvin, Dorothy Leonard, Susan Straus, John Seely Brown 2. Sudhir Warier , Knowledge Mangement, Vikas publishing House 3. Knowledge Retention: Strategies And Solutions – Jay Liebowitz 4. Knowledge Management – Paul Gamble & John Blackwell 5. The Power Of KM: Harnessing The Extraordinary Value Of Knowledge Management – Brent N. Hunter 6. Knowledge Management – Shelda Debowski 7. Knowledge Management: Concepts and Best Practices by Kai Mertins (Editor), Peter Heisig (Editor), Jens Vorbeck (Editor) 8. Awad, E.M (2007). Knowledge Management. Pearson India, Delhi. 9. Fernandez I. B. and Sabherwal, R. (2010). Knowledge Management: System and Resources. PHI Delhi. 10. Kimiz Dalkir (2005). Knowledge Management in Theory and Practice. Elsevier. 11. Tiwana Amrit (1999).The Knowledge Management Toolkit. Prentice Hall PTR.
Reference Books
1. If Only We Knew What We Know: The Transfer of Internal Knowledge and Best Practice by Carla O'dell, C. Jackson Grayson 2. The Selfish Gene , Richard Dawkin 3. The Reality of Magic, Richard Dawkin 4. The Blind watchmaker, Richard Dawkin 5. The greatest show on Earth, Richard Dawkin 6. The extended phenotype, Richard Dawkin

Course Code	Course Name	L – T – P	Credits
TM609	SYSTEMS ENGINEERING FOR MANAGERS	3-0-0	3
Course Objectives: The objective of this course is to prepare students : • To apply fundamental knowledge and skill sets required in the Industrial and Systems Engineering profession. • To adopt a systems approach to design, develop, implement and innovate integrated systems. • To work and communicate effectively with multi-disciplinary team members and different types of stakeholders. • To recognize the need and continue to develop skills and knowledge to embrace changes in society and the profession.			
Course Contents Unit I <i>Systems engineering and the world of modern systems</i> Nature and Scope of Systems Engineering, Origins of Systems Engineering, The Power of Systems Engineering, Examples of Systems Requiring Systems Engineering, Principles of Requirements Management Engineering. Unit II <i>Structure of complex systems:</i>			

System Building Blocks and Interfaces, Hierarchy of Complex Systems ,System Building Blocks; The System Environment; Interfaces and Interactions; Complexity in Modern Systems; Examples of Complex Systems Unit III <i>The system development process</i> Systems Engineering through the System Life Cycle; System Life Cycle; Evolutionary Characteristics of the Development Process; The Systems Engineering Method; Testing throughout System Development; Development process examples Unit IV <i>Systems Engineering Management</i> Managing System Development and Risks; WBS; SEMP; Risk Management Course Outcomes After completing this course, the students will be able to: CO1: Understand engineering design and product lifecycles in the context of the professional career CO2: Elaborate on how intended use guides the development of socio-technical systems, Develop and evaluate systems requirements CO3: Analyse and decompose system requirements into functions and design requirements, Plan the design process CO4: Create a system design concept that can be verified against the requirements and outline how product-service systems can be designed to support in-service systems CO5: Demonstrate professional skills in preparation of professional standard documentation based on templates from a business management system. Text Books 1. B.Dennis M.Buede, The Engineering Design of Systems: Models and Methods, John Wiley& Sons,2011 2. A.Kossiakoff, W.N.Sweet,S.J.Seymour & S.M.Biemer,Systems Engineering: Principles and Practice,Wiley,2011 3. D.J.E.Kasser,A Framework for Understanding Systems Engineering, Book/Surge Publishing,2007 Reference Book 1. George,A. Hazelrigg, Systems Engineering: An Approach to Information-Based Design, Prentice Hall NJ, 1996. 2. Benjamin, A., Blanchard, and Walter,J. Fabrycky, Systems Engineering and Analysis, 3rd Ed., Prentice Hall International Series, Industrial & Systems Engg., 1998 3. B.S.Blanchard, Systems Engineering Management,Wiley,1998			

Course Code	Course Name	L – T – P	Credits
TM613	VALUE ENGINEERING	3-0-0	3

Course Objectives:

- To identify optimal solutions to balance the actual project requirements with the available resources and means, and helping to use analytical and creative thinking.
- To create sufficient awareness of the importance of achieving ideal value for projects or services and eliminating unnecessary costs while raising quality and performance.
- To learn how to start risk management through value engineering and to determine the real costs of projects before entering into the risks of managing changes.
- To evaluate the results of value engineering work and learn how to review its reports.

Course Contents**Unit I**

Introduction to Value Engineering and Value Analysis, Methodology of V.E., Quantitative definition of value, Use value and prestige value, Estimation of product quality/performance, Classification of functions, functional cost and functional worth, Effect of value improvement on profitability

Unit II

Introduction to V.E. job plan / Functional approach to value improvement, Various phases and techniques of the job plan, Life Cycle Costing for managing the total value of a product, Cash flow diagrams, Concepts in LCC, Present Value concept, Annuity cost concept, Net Present Value, Pay Back period, Internal rate of return on investment (IRR), Continuous discounting, Examples and illustrations.

Unit III

Creative thinking and creative judgment, False material, labor and overhead saving, System reliability, Reliability elements in series and in parallel, Decision Matrix, Evaluation of value alternatives, Estimation of weights and efficiencies, Sensitivity analysis, Utility transformation functions, Fast diagramming, Critical path of functions, DARSIRI method of value analysis

Course Outcomes

After completing this course, the students will be able to:

CO1: Understand and explain the fundamental concepts, techniques, and applications of value engineering, including its advantages and its role in improving productivity and decision-making.

CO2: Describe and apply the phases of the value engineering job plan, such as orientation, information, speculation, analysis, and evaluation, to real-world projects

CO3: Analyze and evaluate functions, costs, and worth of products, processes, or services to identify unnecessary costs and improve value.

CO4: Employ value engineering techniques to develop and assess alternative solutions, supporting robust decision-making and optimal resource utilization. CO5: Organize and participate effectively in value engineering teams, understanding team roles and the collaborative nature of value engineering projects.
Text Books
1. Anil Kumar Mukhopadhyaya, Value Engineering: Concepts, Techniques and Applications, Sage Publication. 2. Zimmerman L., Value Engineering Paperback – 2010.
Reference Books
1. Del I. Younker, Value Engineering: Analysis And Methodology, 2. J. Paul Guyer, Value Engineering (Engineering Sound Bites) Kindle Edition

Course Code	Course Name	L – T – P	Credits
TM614	DESIGN MANAGEMENT	3-0-0	3
Course Objectives: • The objective of design management is to develop and maintain an efficient business environment • This course looks at the design process and results from the point of view of all the stake holders including the Owner, Architect, Contractor and Users. • To identify and explore design attributes that positively influence a projects performance and the pitfalls that can derail a project. • To build and manage a successful design team that can reliably deliver a quality project and how that design team can effectively deal with the other team members.			
Course Contents Unit I Introduction; Designer’s view; Philosophical and psychological issues in design; Fostering creativity and innovation; cognition: Action selection, memory, decision making; Perception: Auditory & Visual, errors. Design and Competitiveness: Oligopoly, Monopoly Unit II Requirement elicitation and analysis: QFD, HOQ; Anthropometrics, Human factors & Ergonomics; Environmental design; Industrial design management; basics of work study: time study, motion study; Economic analysis: Break even analysis, profit, Taguchi function. Unit III Collaboration and conflict management; concept of value analysis and value engineering-design perspective; role of computer in design; rapid prototyping; designer as an entrepreneur, designer’s knowledge on Intellectual Property Rights			
Course Outcomes			

After completing this course, the students will be able to: CO1: Understand the various issues in philosophical and psychological perspectives. CO2: Develop design perceptions and its effect on competitiveness. CO3: Learn data elicitation techniques and various analysis useful for design management. CO4: Explore the design thinking, value analysis and value engineering. CO5: Evaluate various applications of computer in design management. CO6: Exploring the knowledge on prototyping, entrepreneur and IPR.
Text Books
1. Oakley, M. (Ed), Design Management – A Handbook of Issues and Methods, Blackwell Publication. 2. Kathryn Best, Design Management: Managing Design Strategy, Process and Implementation 3. Brigitte Borja de Mozota, Design Management: Using Design to Build Brand Value and Corporate Innovation
Reference Books
1. Michel Farr, Design Management. 2. Rachel Cooper, Sabine Junginger and Thomas Lockwood, Design Management.

Course Code	Course Name	L – T – P	Credits
TM616	INTRODUCTION TO ENABLERS OF NATION BUILDING	3-0-0	3
Course Objectives: • To develop the personality and character of the student youth through voluntary community service. • To explain concepts of Entrepreneurship and build an understanding about business situations in which entrepreneurs act . • To create awareness about disaster and its mitigation process among people			
Course Contents			
Unit I <i>Introduction and Basic Concepts of National Service Scheme (NSS):</i> History, philosophy, aims & objectives of NSS, Emblem, flag, motto, song, badge etc., Organizational structure, roles and responsibilities of various NSS functionaries.			
Unit II <i>Life competencies & Disaster Management:</i> Definition and importance of life competencies, Communication, Inter Personal, Problem-solving and decision-making, Introduction to Disaster Management, classification of disasters, Role of youth in Disaster Management			
Unit III			

<i>Entrepreneurship Development: Definition & Meaning, Qualities of good entrepreneur, Steps/ways in opening an enterprise, Role of financial and support service Institutions.</i>	
Course Outcomes	
After completing this course, the students will be able to: CO1: Evolution, basic concept and structure of National service scheme. CO2: Problem solving and decision making approach for improvement of life competencies. CO3: This guides for entrepreneurship development ways and means.	
Text Books	
1. Disaster Management, Harsh k Gupta 2. Management of natural disasters in developing countries, H N Srivastava 3. Entrepreneurship Development, S Anil Kumar	
Reference Books	
1. Chhatrapati Shahu – The Pillar of Social Democracy, Ed. P.B. Salukhe. 2. National Service scheme Manual, Govt. of India. 3. Training Programme on National programme scheme, TISS. 4. Orientation courses for N.S.S. programme officers, TISS. 5. Case material as Training Aid for field workers, Gurmeet Hans	

Course Code	Course Name	L – T – P	Credits
TM618	OPERATIONS MANAGEMENT	3-0-0	3
Course Objectives: • To obtain an understanding of quality management practice to facilitate organizational effectiveness. • To achieve efficiency and productivity within an organization's processes. This involves finding ways to minimize waste, reduce costs, and maximize output. • To leverage efficient and productive operations, maintain high-quality standards, control costs, manage the supply chain effectively, foster innovation, align strategies, and prioritize customer satisfaction.			

Course Contents			
Unit I Managing operations; planning and design of production and operations systems. Service characteristics. Facilities planning location, layout and movement of materials. Line balancing. Analytical tools and techniques for facilities planning and design.			
Unit II Production forecasting. Aggregate planning and operations scheduling, Production Planning and Control. Purchasing, Materials Management and Inventory control and JIT Material Requirements Planning. MRPII, ERP, Optimization techniques applications.			
Unit III Work Study, Operations Strategies, Theory of constraints, Maintenance management and equipment policies. Network planning and control. Line of Balance, World class manufacturing and factories of the future, Case studies.			
Course Outcomes			
After completing this course, the students will be able to: CO1: Understanding production and operations systems for manufacturing industry. CO2: Learning various tools and techniques for facilities planning and design CO3: Various techniques for productions and management of inventory concept CO4: Learning the concept of work study, time study, quality engineering, SPC and Maintenance concepts. CO5: Exploring world class manufacturing facilities and their practices as case study			
Text Books			
1. Operations Management: Theory and Practices, B. Mahadevan; 3rd edition, Pearson. 2. Production and Operations Management; R. Paneerselvam, 3rd edition, PHI.			
Reference Books			
1. F. Robert Jacobs, Ravi Shankar, and Richard B. Chase: Operations & Supply Chain Management (17th Edition), McGraw-Hill Publishing Company Ltd, New Delhi (2024) 2. Operations Management; J. Heizer and B. Render; 11th edition, Pearson. 3. Operations Management; Russell and Taylor; 7th edition, Wiley.			

Course Code	Course Name	L – T – P	Credits
TM619	ADVANCED PROJECT MANAGEMENT TECHNIQUES	3-0-0	3

Course Objectives: • Project, Program, and Portfolio Management is the principal means by which operational and strategic changes are managed in today's organizations. • To learn concepts and techniques that will prepare individuals and the enterprise to use projects, programs, and portfolios management as a strategic framework to prepare the organization for its future.			
Course Contents Unit I Advanced concepts in Project Management: Agile PM, Capability Maturity Model (CMM), Earned Value Analysis (EVA) and Earned Duration Analysis (EDA) Unit II Software Project Management: Software testing and quality Management, Effort estimating and scheduling, Project Monitoring and control, Reviews, Risk Management, Tools for software project such as MS project Unit III Applications and case studies in Project Management, Management of multiple projects Unit IV Collaborative Product Development: Integrated Product Design, User Experience Design, Internal & External Collaborations, Integrated Process & Product Development.			
Course Outcomes			
After completing this course, the students will be able to: CO1: To get awareness of various advanced project management concepts. CO2: Exploring software project management and tools and techniques for managing projects. CO3: Design and Development of product process and intricacies in project phases. CO4: The process of collaboration for product development and integration process. CO5: Various case studies and projects from different industries as applications of project management concept.			
Text Books			
1. Ravi Chopra, Software Project Management, Katson Books. 2. Sanjay Mohapatra, Software Project Management, Cengage Learning. 3. Rishabh Anand, Software Project Management, Katson Books.			
Reference Books			
1. John M. Nicholas and Herman Steyn, Project Management for Business, Engineering, and Technology: Principles and Practices (Third Edition), Elsevier (2008). 2. Pankaj Jalote: Software Project Management in Practice, Pearson 3. Bob Hughes, Mike Cotterell, Rajib Mall: SOFTWARE PROJECT MANAGEMENT (5th edition), -McGraw Hill Education. 2016 4. Taylor James: Managing Information Technology Projects: Applying Project Management Strategies To Software, Hardware, And Integration Initiatives 1st Edition, AMACOM			
Course Code	Course Name	L – T – P	Credits
TM620	ACCOUNTING AND FINANCE FOR TECHNOLOGISTS	3-0-0	3

Course Objectives: • Demonstrate the ability to utilize the accounting cycle to record transactions, process information and prepare financial statements for a business. • To demonstrate knowledge of budgeting and product costing techniques and methods related to the control and evaluation of business operations. • To create a small business and demonstrate the ability to analyze and evaluate possible outcomes using industry standards and best practices. Students will understand and apply fundamental concepts required to start and run a small business.			
Course Contents Unit I Introduction to accounting, accountability, transparency, responsibility; Basic accounting concepts and financial statements, sources and use of finance, Basics of Project finance in Public domain, feasibility study, Asset Funding. Unit II Social cost benefit analysis; Return on Investment, Cost of Capital, Audit and control; Cost concepts and profit centers and responsibility accounting; costing and profitability analysis; Good costs vs. Bad costs. Unit III Basics of contracts, Cost escalation clause in contracts and consequences, Planning and budgeting; Basic concepts of working capital, Basics of financing of imports, exchange rate risk in capital expenditure decisions			
Course Outcomes			
After completing this course, the students will be able to: CO1: Understand the basic concepts of accounting and finance. Understanding the process of financing the projects, feasibility and funding. CO2: Acquire the knowledge on social cost benefit analysis, ROI, capita, audit and profit concepts. CO3: Focusing on contracts, cost escalation and its consequence. CO4: Determine Planning and budgeting for projects and its implication on it. CO5: Risk analysis of accounting and financing while import and export of product and projects and its case studies.			
Text Books			
1. Anthony, Robert N (1984): Management accounting, Text and Cases, Richard D. Irwin, Inc. Illinois 2. Ernest, W. Walker (1976): Essentials of Financing Management, Prentice Hall, New Delhi. 3. Gestenberg, Charles W. (1962): Financial Organisation and Management of Business Asia Publishing, Sultan Chand and Sons 4. Pandey, I.M. (1983): Financial Management, Vikas Publishing House Pvt. Ltd., New Delhi. 5. Jain S P ,Narang K L , Cost and Management Accounting, Kalyani Publishers 6. Khan a, Jain, Financial Management, Tata McGraw Hill			

7. Dr. V K Goyal, Financial Accounting, Excel Books
Reference Books
1. Van, Home James C. (1971): Fundamentals of Financial Management Prentice Hall Inc. Englewood Cliffs, New Jersey. 2. Vyas, J.N. (1983): Financing and Industrial, N.K. Vyas, Family trust, Ahmedabad. 3. Walker, Ernest, W (1976): Essentials of Financing Management,— Prentice Hall of India Ltd., New Delhi.

Course Code	Course Name	L – T – P	Credits
TM621	ARTIFICIAL INTELLIGENCE (AI) IN MANAGEMENT	3-0-0	3
Course Objectives: - To provide foundational knowledge of AI and its principles, preparing students for AI integration in management. - To teach various AI techniques and models, enabling students to choose the appropriate methods for different applications. - To guide students on the responsible deployment of AI, covering strategy formulation, investment, valuation, and risk management. - To illustrate the transformative impact of AI on management practices through case studies and real-world examples.			
Course Contents Unit I <i>Beginning of an AI Journey:</i> AI Fundamentals, 7 Principles of an AI Journey, Becoming Data Ready – The TUSCANE Approach, Data Dictionary, Data Pre-processing, Choosing the right solution – The FAB-4 model Unit II <i>Choosing the right AI technique:</i> Inside AI Laboratory- Data and models, AI modelling framework, Classification, Regression, Decision trees, Ensemble learning, Clustering, Association rules, Reinforcement learning, and Natural Language processing, Deep Learning-, ANN, CNN Unit III <i>Using AI successfully and responsibly:</i> AI adoption and valuation- Phases of AI deployment, AI investment and valuation, AI strategy, Policy, and Risk management- strategy formulation, Principles of human-AI work policy and Risk with AI Unit IV Case Studies/Tutorial on how AI transforms management practices and organizational dynamics.			
Course Outcomes			

After completing this course, the students will be able to:

CO1: To attain foundational AI knowledge, including the 7 Principles of an AI Journey. **CO2:** To comprehend diverse AI techniques and develop expertise in selecting the most suitable AI technique for specific applications.

CO3: To acquire the know-how to deploy AI responsibly in organizations, covering AI adoption phases, investment and valuation strategies, and risk management

CO4: To analyze case studies and tutorials illustrating AI's transformative impact on management practices and organizational dynamics, offering valuable insights into real-world AI applications.

Text Books

1. Artificial Intelligence: A Modern Approach, Prentice-Hall, Third Edition (2009) Stuart Russell & Peter Norvig
2. Applied artificial intelligence: a handbook for business leaders by Mariya Yao, Adelyn Zhou, Marlene Jia
3. Artificial Intelligence and Machine Learning by Finlay, Steven
4. Artificial Intelligence Basics A Non-Technical Introduction by Tom Taulli

Reference Books

1. 1. AI for People and Business: A Framework for Better Human Experiences and Business Success 1st Edition by Alex Castrounis
2. Machine Learning For Absolute Beginners: A Plain English Introduction (Second Edition) (Machine Learning From Scratch Book by Oliver Theobald
3. Fundamentals of Machine Learning for Predictive Data Analytics Algorithms, Worked Examples, and Case Studies By John D. Kelleher, Brian Mac Namee and Aoife D'Arcy
4. Artificial Intelligence and Machine Learning for Business: A No-Nonsense Guide to Data Driven Technologies by Steven Finlay
5. Artificial Intelligence: What Everyone Needs to Know by Jerry Kaplan
6. The Future of Leadership: Rise of Automation, Robotics and Artificial Intelligence by Brigitte Tasha Hyacinth

Course Code	Course Name	L – T – P	Credits
PGC-601	RESEARCH METHODOLOGY AND IPR	2-0-0	2

Course Objectives:

This course is designed to enable students to:

- To identify and discuss the complex issues inherent in selecting a research problem, selecting an appropriate research design, and implementing a research project.
- To identify and discuss the concepts and procedures of sampling and data collection.
- To enable the students to prepare report writing and framing Research proposals.

- To make the students aware of their rights for the protection of their invention done in their project work

Course Contents

Unit I

Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Unit II

Effective literature studies approaches, analysis Plagiarism, Research ethics

Unit III

Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Unit IV

Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Unit V

Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications

Unit VI

New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies.

After completing this course, the students will be able to:

CO1: Understanding the fundamentals of research and its methodology

CO2: Choose the appropriate research design and develop appropriate research hypothesis for a research project

CO3: Knowledge of manuscript preparation, patents and Intellectual property

CO4: Technology transfer and application of IPR in various domains

Text/ Reference Books

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students"
2. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
3. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
4. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.
5. Mayall, "Industrial Design", McGraw Hill, 1992.
6. Niebel, "Product Design", McGraw Hill, 1974.

8. Asimov, “Introduction to Design”, Prentice Hall, 1962. 9. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “ Intellectual Property in New Technological Age”, 2016. 10. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008			
Course Code	Course Name	L – T – P	Credits
PGC-602	AUDIT COURSE	2-0-0	0
Course Objectives: • To develop and enhance one's self confidence and positive behavior or attitude as a professional. • To be able to learn strategies and techniques of being a better individual with a positive attitude and behavior.			
Course I English for Research Paper Writing Planning and preparation, identifying research problem, research questions, structuring paragraph, developing a persuasive style in writing, objectivity, avoiding ambiguity etc. Methodology, literature review/survey, writing introduction, result discussion, analyzing findings, conclusion and various sections. .			
Course II Disaster Management Introduction: Concepts and definitions: Disaster, hazard, vulnerability, resilience, risks, frequency and details, capacity, impact, prevention, mitigation. Disaster Risk Reduction (DRR) Disaster management: Applications and case studies			
Course III Sanskrit for Technical Knowledge Alphabets in Sanskrit, Past/Present/Future Tense, Simple Sentences Technical information about Sanskrit Literature Technical concepts of Engineering-Electrical, Mechanical, Architecture, Mathematics			
Course IV Value Education Values and self-development Personality and Behavior Development Character and Competence			
Course V Constitution of India			

History of Making of the Indian Constitution
Philosophy of the Indian Constitution
Contours of Constitutional Rights & Duties
Organs of Governance
Local Administration
Election Commission

Course VI

Pedagogy Studies

Introduction and Methodology : Aims and rationale, Policy background, Conceptual framework and terminology

Thematic overview: Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries.

Evidence on the effectiveness of pedagogical practices :Professional development: alignment with classroom practices and follow-up support

Course VII

Stress Management by Yoga

Definitions of Eight parts of yoga.(Ashtanga)

Yam and Niyam. Do's and Don't's in life.

Asan and Pranayam

Course VIII

Personality Development through Life Enlightenment Skills

Holistic development of personality

Approach to day to day work and duties

Course Outcomes

After completing this course, the students will be able to:

CO1: Understand that how to improve your writing skills and level of readability.

CO2: Understanding foundations of hazards, disasters and associated natural/social phenomena.

CO3: Understanding basic Sanskrit language. Ancient Sanskrit literature about science & technology can be understood.

CO4: Students will gain deeper understanding about the purpose of their life. Students will understand and start applying the essential steps to become good leaders.

CO5: Demonstrate a broad and coherent body of knowledge with depth in the underlying principles and concepts and integrate knowledge of the diversity of cultures and peoples.

CO6: Use practical tools for stress management in educational environments and cope with stressful situations at the

CO7: To develop inter personal skills and be an effective goal-oriented team player.

Text Books

1. Goldbort R *Writing for Science*, Yale University Press (available on Google books): 2006
2. Day R: *How to write and Publish a Scientific Paper*, Cambridge University Press :2006
3. Adrian Wallwork, *English for Writing Research Papers*, Springer New York, 2011
4. Chakroborty, S.K. “Values and Ethics for organizations Theory and practice”, Oxford University Press, New Delhi
5. Tushar Bhattacharya, “Disaster Science and Management”, McGraw Hill India Education P Ltd., 2012.
6. Pradeep Sahni, “Disaster Mitigation: Experiences and Reflections”, Prentice Hall, 2004.
7. Singhal J.P. “Disaster Management”, Laxmi Publications, 2010.
8. Donald Hyndman & David Hyndman, “Natural Hazards & Disasters”, Cengage Learning, 2010.
9. Singh B.K., Handbook of Disaster Management: Techniques & Guidelines, Rajat Publication, 2008.
10. Govt. of India: Disaster Management Act, Government of India, New Delhi, 2005.
11. ‘Yogic Asanas for Group Training-Part-I’: Janardan Swami Yogabhyasi Mandal, Nagpur
“Rajayoga or conquering the Internal Nature” by Swami Vivekananda, Advaita Ashrama (Publication Department), Kolkata

Reference Books

1. S.C. Parja & Vikram Kate. Writing and Publishing a Scientific Research Paper. Springer: 2017.
2. Highman N, Handbook of Writing for the Mathematical Sciences, Highman’s Book: 1998.
3. “Abhyaspustakam” – Dr. Vishwas, Samskrita-Bharti Publication, New Delhi
4. “Teach Yourself Sanskrit” Prathama Deeksha-Vempati Kutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication
5. “India’s Glorious Scientific Tradition” Suresh Soni, Ocean books (P) Ltd., New Delhi.
6. The Constitution of India, 1950 (Bare Act), Government Publication.
7. Dr. S. N. Busi, Dr. B. R. Ambedkar framing of Indian Constitution, 1st Edition, 2015.
8. M. P. Jain, Indian Constitution Law, 7th Edn., Lexis Nexis, 2014.

9. D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015
10. Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, Compare, 31 (2):245-261.
11. Agrawal M (2004) Curricular reform in schools: The importance of evaluation, Journal of Curriculum Studies, 36 (3): 361-379.
12. Alexander RJ (2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.

NPTEL / SWAYAM COURSES- SEMESTER - I.

Course Code	Course Name	L – T – P	Weeks
NPTEL	Human Resource Development	3-0-0	12

Course Objectives:

- Equip students to design, implement, and evaluate HRD strategies like coaching, mentoring, and career development.
- Develop understanding of HRDs strategic role in improving performance, learning, intellectual capital, and ethical global practices.

Course contents

Unit I

Foundations of Human Resource Development

Introduction to Human Resource Development:

Emergence of HRD, Critical HRD Roles, Challenges for HRD, HRD in Global Perspective, HRD–Performance Link, Strategic Perspective of HRD, HRD Process Model: Identification of HRD Needs, Design and Development of HRD Programmes, HRD Process Model: Methods of Implementation, Evaluation of HRD Programmes

Unit II

HRD Interventions for Employee Development

Employee Coaching and Performance Management, HRD Interventions: Mentoring for Employee Development, Employee Counseling for HRD, Competency Framework of HRD

Unit III

Strategic HRD, Career Development & Organizational Learning

Career Planning, Management, and Development, Intellectual Capital (IC), Its Measurement and Management, HRD, Organizational Learning, and Learning Organizations, The Future of HRD and HRD Ethics

Course outcomes
After completing this course, the students will be able to:
CO1: Understand HRD fundamentals, global perspectives, and apply the HRD process to design and evaluate effective programs.
CO2: Develop coaching, mentoring, and performance management skills to enhance employee and organizational outcomes.
CO3: Design career development programs, manage intellectual capital, and foster continuous organizational learning and ethical HRD practices.
Text Books
1. "Fundamentals of Human Resource Development" by Robert L. Craig 2. "Human Resource Development" by Jon M. Werner and Randy L. DeSimone 3. "Employee Training and Development" by Raymond A. Noe
Reference Books
1. "The ASTD Handbook of Training Design and Delivery" 2. "Effective Human Resource Development: A Practical Guide" by Larry Chiebra 3. "Strategic Human Resource Development" by James P. Russell

Course Code	Course Name	L – T – P	Weeks
NPTEL	HRM for Non-HR Managers	3-0-0	12
Course Objectives: - Understand HRM principles and practices to enhance organizational effectiveness. - Develop analytical and strategic skills to tackle modern HR challenges and leverage technology for sustainable growth.			
Course Contents Unit I Foundations and Core Functions of HRM Human Resource Management (HRM): Meaning and Importance, The Role of HRM in Business and Important Functions, HR Planning (Manpower Planning in Previous Times), Developing Job Descriptions and Job Specifications (Parts 1 & 2), Recruitment (Parts 1 & 2), Testing and Selection, Interviews, Employee Orientation and Onboarding Unit II			

Compensation, Legal Aspects, and Performance Management Compensation-1: Pay and Perquisites, Rewards and Incentives, Compensation-2: Legal Provisions Related to Compensation, Training and Development, HR Policies, Discipline and Grievance Management, Legal Provisions for Managing Discipline and Grievance, Performance Management, Career Paths and Succession Planning, Managing Employee Separation, Conducting Employee Surveys Unit III Strategic HRM, Technology Integration, and Emerging Trends Legal Compliance and HRM-1: Trade Unions, Industrial Disputes, and Standing Orders, Legal Compliance and HRM-2, Employee Retention-1: Turnover Optimization and Retention Strategies, Employee Retention-2: Engagement, Involvement, Commitment, and Satisfaction, ICT and HRM: HR Information Systems, HR Analytics, HR Scorecard and Organizational Effectiveness, HRM in Mergers and Acquisitions, Knowledge Management, Learning Organization, and HRM, HR Outsourcing, Directions for Future Development in HRM
Course outcomes After completing this course, the students will be able to: CO1: Understand and apply core HRM functions like recruitment, compensation, and training in organizations. CO2: Analyze HR policies and legal frameworks to manage discipline, grievances, and labor law compliance. CO3: Use modern HR tools and strategies to boost employee engagement, retention, and performance.
Text Books Fundamentals of Human Resource Management <i>By Raymond A. Noe, John R. Hollenbeck, Barry Gerhart & Patrick M. Wright</i> Essentials of Human Resource Management <i>By Gary Dessler</i> The Essential HR Handbook: A Quick and Handy Resource for Any Manager or HR Professional <i>By Sharon Armstrong & Barbara Mitchell</i>
Reference Books Armstrong's Handbook of Human Resource Management Practice <i>By Michael Armstrong</i> The SHRM Essential Guide to Human Resources <i>By Society for Human Resource Management</i> The HR Scorecard: Linking People, Strategy, and Performance <i>By Brian E. Becker, Mark A. Huselid & David Ulrich</i>

Course Code	Course Name	L – T – P	Week
NPTEL	Organization Behaviour	3-0-0	12
Course Objectives: • Understand fundamental concepts and models of Organizational Behaviour and workplace interactions. • Develop analytical and interpersonal skills to influence human behaviour through motivation, leadership, communication, and culture.			
Course Contents Unit I Fundamentals of Organisational Behaviour Organisational Behaviour: Meaning and Concept, Organisational Behaviour: Importance and Fields of Study, Roles and Skills of Managers, Organisational Behaviour: Challenges, Field of OB: Individual, Groups & Systems as Building Blocks, Organisational Behaviour Models, Evolution of Organisational Behaviour – Part 1: Evolution of Organisational Behaviour , Part 2: Researches in Organisational Behaviour, International Organisational Behaviour Unit II The Individual in the Organisation Perception, Personality, Learning: Concept and Theories, Values, Attitude: Meaning and Concept, Attitude: Formation and Change, Motivation: Content Theories, Motivation: Process Theories, Job Satisfaction, Emotions and Emotional Intelligence Unit III Group Dynamics, Leadership, and Organisational Systems Formation of Groups, Types of Groups, Team Dynamics, Group Decision Making, Interpersonal Relations, Communication: Nature, Types and Barriers, Leadership: Nature, Importance and Styles, Theories of Leadership, Power and Politics, Conflict, Foundations of Organization Structure, Organizational Design, Diversity and Its Management, Stress among Employees, Work-Life Balance, Organizational Change and Development, Organizational Culture, Employee Empowerment, Learning Organisation, Ethical Behaviour in Organizations			
Course outcomes			

After completing this course, the students will be able to: CO1: Explain the key concepts and theories of Organizational Behaviour at the individual, group, and organizational levels. CO2: Assess and apply behavioral frameworks related to perception, motivation, personality, learning, leadership, and communication to solve workplace challenges. CO3: Analyze group dynamics and organizational processes such as decision-making, conflict resolution, organizational change, and development for enhancing organizational effectiveness.
Text Books
1. Organizational Behavior <i>Stephen P. Robbins & Timothy A. Judge</i> 2. Organizational Behavior: Improving Performance and Commitment in the Workplace <i>Jason A. Colquitt, Jeffery A. Lepine & Michael W. Wesson</i> 3. Organizational Behavior, <i>John R. McShane & Mary Ann Von Glinow</i>
Reference Books
1. The SAGE Handbook of Organizational Behavior (2 Vols.) <i>Edited by Steve Clegg, Cynthia Hardy & Tom Lawrence</i> 2. The Oxford Handbook of Organizational Behavior, <i>Edited by Michael G. Pratt, Anja Van de Ven, Barbara Czarniawska & Michael Beyer</i> 3. APA Handbook of Industrial and Organizational Psychology (Vol. 1 & 2), <i>Edited by Sheldon Zedeck</i>

Course Code	Course Name	L – T – P	Weeks
NPTEL	HR Analytics	3-0-0	12
Course Objectives: • To introduce the concepts, tools, and frameworks of HR Analytics with a focus on applying data-driven decision-making to core HR functions such as recruitment, training, performance, and compensation. • To equip learners with practical skills in data visualization tools like Power BI, Excel, and Tableau to analyze and present HR data for strategic insights and organizational effectiveness.			
Course Contents Unit I Foundations of HR Analytics and Visualization Tools			

Introduction to HR analytics, HR Data Preparation & Development of HR metrics, Data science framework, Pitfalls of data science framework and Basics of data visualization, Developing HR analytics unit and culture, List of books, Introduction to data visualization, Data Visualization Power BI – 1, Data Visualization Power BI – 2, Data Visualization Power BI – 3, Data Visualization Excel - 1, Data Visualization Excel - 2, Data Visualization Tableau – 1, Data Visualization Tableau – 2, Data Visualization Tableau – 3, Data Visualization Tableau – 4, Data Visualization Tableau – 5

Unit II

HR Analytics Applications in Recruitment, Selection, and Training

Steps of recruitment, Managerial challenges of recruitment -1, Managerial challenges of recruitment – 2, Recruitment Analytics – 1, Recruitment Analytics – 2, Recruitment Analytics – 3, Recruitment Analytics – 4, Steps of employee selection process, Managerial challenges of employee selection -1, Managerial challenges of employee selection -2, Selection Analytics – 1, Selection Analytics – 2, Selection Analytics – 3, Selection Analytics – 4, Data Visualization of Recruitment & Selection, Steps of training, Managerial challenges of employee training -1, Managerial challenges of employee training -2, Training Analytics – 1, Training Analytics – 2, Training Analytics – 3, Training Analytics – 4

Unit III

HR Analytics in Development, Performance, and Compensation

Steps of Employee development, Managerial challenges of employee development -1, Managerial challenges of employee development -2, Employee Development Analytics – 1, Employee Development Analytics – 2, Employee Development Analytics – 3, Employee Development Analytics – 4, Data Visualization of Training & Development, Steps of performance management, Managerial challenges of performance management -1, Managerial challenges of performance management – 2, Performance Analytics -1, Performance Analytics -2, Performance Analytics -3, Performance Analytics -4, Steps of compensation management, Managerial challenges of compensation management -1, Managerial challenges of compensation management -2, Compensation Analytics – 1, Compensation Analytics – 2, Compensation Analytics – 3, Compensation Analytics – 4, Data Visualization of Performance & Compensation

Course outcomes

After completing this course, the students will be able to:

CO1: Demonstrate an understanding of HR analytics frameworks and the application of data science principles in human resource management.

CO2: Develop and interpret HR metrics using analytical tools to address challenges in recruitment, selection, training, performance, and compensation management.

CO3: Utilize visualization platforms such as Power BI, Excel, and Tableau to effectively communicate HR insights to support strategic workforce decisions.

Text Books

1. Predictive HR Analytics: Mastering the HR Metric, <i>Martin R. Edwards & Kirsten Edwards</i> 2. Practical HR Analytics: Using Data to Inform, Transform, and Empower HR Decisions <i>Shonna D. Waters & Valerie N. Streets</i> 3. Strategic Workforce Analytics: Translating HR Strategy into Business Impact, <i>Thomas H. Davenport, Jeanne Harris & Jeremy Shapiro</i>
Reference Books
1. The Power of People: How Successful Organizations Use Workforce Analytics to Improve Business Performance, <i>Nigel Guenole, Jonathan Ferrar & Sheri Feinzig</i> 2. People Analytics in the Era of Big Data: Changing the Way You Attract, Acquire, Develop, and Retain Talent, <i>Jean Paul Isson & Jesse S. Harriott</i> 3. People Analytics: How Social Sensing Technology Will Transform Business and What It Tells Us about the Future of Work, <i>Ben Waber</i>

NPTEL / SWAYAM COURSES- SEMESTER - II.

Course Code	Course Name	L – T – P	Weeks
NPTEL	AI in Human Resource Management	3-0-0	12
Course Objectives: • To understand the fundamentals of Artificial Intelligence (AI) in Human Resource Management (HRM) . • To explore innovative applications of AI in HRM, including AI-augmented HRM, the use of generative AI, and the integration of AI with HR practices to drive organizational capabilities and performance.			
Course Contents Unit I Foundations of AI in HRM Deploying AI in HR practices, Introduction to AI tools, Leveraging AI for diversity management, Decision making, Adoption of AI in task automation, recruitment, and talent acquisition, HR metrics, Role of AI in performance management, Application of AI in onboarding, Using AI in person–job fit, HR analytics, People analytics using AI, HR administration application, SMART HRM, Using AI for employee retention, Using AI in performance appraisal, Using AI in employee training, Using AI in workforce planning, Ethical concerns in using AI in HRM Unit II Innovation and Advanced Applications of AI in HRM AI-augmented HRM, Learning and development programmes, Disruptive innovation in HRM, HRM in the era of generative AI, Building organizational capabilities through AI-driven HRM,			

Metaverse in HRM, Challenges of AI adoption in HRM, HRM digitalization success and future opportunities, AI in career succession planning

Unit III

Emerging Trends, Tools, and the Human-AI Interface

AI in sustaining green HRM, Emerging trends of AI-based HRM, Benefits of synergizing AI and HRM, AI in compensation and benefits, AI in compliance, AI-mediated knowledge management, AI in SHRM, HRP and HR chatbots, Using AI in enhancing employee experience, HR and company culture, Adopting AI in managing company culture, Co-existence of HR and AI

Course outcomes

After completing this course, the students will be able to:

CO1: Understand and apply AI tools and techniques to enhance HR functions such as recruitment, onboarding, training, and performance management, aligning them with business goals.

CO2: Analyze and evaluate the impact of AI-driven innovations on HR practices, including AI in performance management, career succession planning, and HR digitalization.

CO3: Identify and address ethical challenges in deploying AI in HRM, and develop strategies for harmonizing the coexistence of AI and human HR professionals in shaping company culture and employee experience.

Text Books

1. "Artificial Intelligence for HR: Use AI to Support and Develop a Successful Workforce"
By Ben Eubanks
2. "AI in Talent Management" *By Rajan Gupta*
3. "Digital HR: A Guide to Technology-Enabled Human Resources" *By Deborah D. Waddill*

Reference Books

1. "The Future of Work: Robots, AI, and Automation" *By Darrell M. West*
2. "Artificial Intelligence for HR: Practical Guide to the Application of AI Techniques in Human Resource Management"
3. "Handbook of Research on Artificial Intelligence in Human Resource Management"

Course Code	Course Name	L – T – P	Weeks
NPTEL	Supply Chain Digitization	3-0-0	12
Course Objectives: To provide a comprehensive understanding of the fundamentals and strategies involved in Supply Chain Management (SCM), including supply chain segmentation and design.			

- To examine the digital infrastructure supporting supply chains, including product tracking, traceability, and advanced technologies such as Digital Twins, ERP, and Industry 4.0.

Course Contents

Unit I

Fundamentals and Strategy in Supply Chain Management

Introduction to Supply Chain Management, Fundamentals of Supply Chain Management, Supply Chain Segmentation, Supply Chain Design & Operations Strategies, Supply Portfolios, Postponement

Unit II

Digital Business and Analytics in Supply Chains

Role of Digital Business in Supply Chains, Introduction to Platform Economy, Channel Structures in the Supply Chain, Decentralized vs Centralized, Dual Channels, Brick & Mortar, Multi-Channels, Omni Channels, Analytics in Supply Chain Management, Descriptive Analytics, Predictive Analytics, Prescriptive Analytics, Application of AI/ML in Forecasting & Demand Analytics, Supply Chain Network Optimization, Intelligent Decision Tool Development in Supply Chains

Unit III

Digital Infrastructure and Advanced Technologies in Supply Chains

Digital Infrastructure for Supply Chains, Product Tracking & Traceability, Information Systems, ERP, WMS, TMS, Digital Twins, Control Towers, Industry 4.0, Blockchains, Digital Payments

Course outcomes

After completing this course, the students will be able to:

CO1: Explain the core principles of Supply Chain Management, design effective supply chain strategies, and implement practices like segmentation, supply portfolios, and postponement.

CO2: Develop an understanding of the role of digital businesses, platform economies, and modern channel structures (multi-channel, omni-channel) in optimizing supply chains.

CO3: Utilize advanced technologies like AI/ML, blockchains, and Industry 4.0 for improving supply chain operations, from forecasting and employee decision-making to payment systems and digital transformations.

Text Books

1. "Supply Chain Management and Advanced Planning: Digital Innovations and Analytics" *By Hartmut Stadtler, Christoph Kilger, and Herbert Meyr*

2. "Digital Supply Networks: Transform Your Supply Chain and Gain Competitive Advantage with Disruptive Technology and Reimagined Processes" <i>By Thomas G. Goldsby, Dawn Iacobucci, and M. Eric Johnson</i> 3. "Designing and Managing the Digital Supply Chain: The Supply Chain Management Collection" <i>By Dmitry Ivanov</i>
Reference Books
1. "Supply Chain Management: Strategy, Planning, and Operation" <i>By Sunil Chopra and Peter Meindl</i> 2. "The Digital Supply Chain: Guiding Principles for Driving Business Innovation" <i>By Bart L. MacCarthy and Dmitry Ivanov</i> 3. "Logistics 4.0: Digital Transformation of Supply Chain Management" <i>Edited by Turan Paksoy, Gerhard W. Weber, and Çağrı Haktan Ekici</i>

Course Code	Course Name	L – T – P	Weeks
NPTEL	Modelling and Analytics for Supply Chain Management	3-0-0	12
Course Objectives: • To introduce students to the fundamental concepts of supply networks and analytics, including performance measures, distribution networks, and the SCOR model. • To guide students in designing and optimizing global supply chain networks using multi-period models.			
Course Contents Unit I Introduction to Supply Network and Analytics in Supply Chains Introduction to Supply Network, Performance Measures for Efficiency and Effectiveness, SCOR Model, Strategic Fit and Scope, Types of Distribution Networks, Analytics in Management, Design of Distribution Networks, Linear Programming, Rating Method, Ranking Method, Borda Count, Clustering, Goal Programming, Multi-Criterion Decision Making (MCDM) Techniques, Transportation Models, Route Planning, Transshipment, Shipment Schedule, Flow Path Optimization Unit II Warehousing, Inventory, and Performance Analytics Warehouse Location Problem, MILP Formulation, Location with Foreign Exchange Risks, Space Calculation for Warehouse, Non-linear Optimization for Warehouse Space Allocation, Data Envelopment Analysis for Competitive Comparisons, Strategic Action Plans for Improving Efficiencies of Non-performing DMUs, Stochastic Frontier Analysis, Elementary Concepts Related to Inventory Management, Economic Order Quantity (Instantaneous Replenishment), Economic Production Lot Size, Inventory Model with Planned Shortages, Inventory Management Under Uncertainty, Concept of Safety Stock, Continuous Review System, Periodic Review System, Newsvendor Model, Expected Lost Sales, Expected Sales, Expected Leftover Inventory, Expected Profit, Fill Rate, In-Stock Probability, Stock-Out			

Probability, Choosing an Order-up-to Level to Meet a Target Service Level, In-Stock Probability, Desired Fill-Rate, Assemble-to-Order, Make-to-Order, Quick Response with Reactive Capacity, Reducing Mismatch Costs with Make-to-Order Unit III Modeling Coordination, Risk Analytics, and Global Supply Chain Design Information Distortion in Supply Network, Bullwhip Effect, Coordination and Collaboration Modeling in Supply Networks, Mapping the Riskiness Profile of a Country, Taxation, Mapping the Riskiness Profile of Possible International Routes, Designing the Route Plan Based on Riskiness Profile, Design and Optimization of Global Supply Chain Networks, Multi-period Supply Chain Network Design
Course outcomes
After completing this course, the students will be able to: CO1: Analyze and model supply network performance using various decision-making techniques and frameworks like the SCOR model. CO2: Assess risks associated with international supply chain routes and optimize route plans based on risk profiles and taxation considerations. CO3: Design and optimize global supply chain networks, addressing complexities of multi-period supply chain models to improve operational efficiency.
Text Books
1. "Supply Chain Engineering: Models and Applications" <i>By A. Ravi Ravindran</i> 2. "Supply Chain Management: Modeling, Planning and Control" <i>By Janat Shah</i> 3. "Supply Chain Engineering: Models and Methods for Effective Resource Management" <i>By Alexandre Dolgui and Jean-Marie Proth</i>
Reference Books
1. "Designing and Managing the Supply Chain: Concepts, Strategies and Case Studies" <i>By David Simchi-Levi, Philip Kaminsky, and Edith Simchi-Levi</i> 2. "Handbook of Supply Chain Management" <i>By James B. Ayers</i> 3. "Operations Research Applications in Health Care Management" <i>By Cengiz Kahraman and Nilay Celikbilek</i>

Department of Electronics Engineering

M. Tech. in Electronics and Communication Engineering **(Signal Processing and AI)**

Semester I

Sl. No	Course Type	Course Code	Course Title	Contact Hours/ Week		Credits
				L	P	
1.	PSC-1	EE602	Advanced Digital Signal Processing	3	0	3
2.	PSC-2	EE620	SOC and Embedded Systems	3	0	3
3.	PSC-3	EE667	Mobile and Satellite Communication	3	0	3
4.	PSC-4	EE668	Machine Learning for Signal Processing	3	0	3
5.	PE-I	E1/EE671	Elective 1/Convex Optimization for Signal Processing	3	0	3
6.	PSL/PSC/PE	EESL01	Signal Processing Laboratory I	0	6	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total	17	6	20

PSC: Program Specific Core; PSL: Program Specific Lab; PE: Professional Elective

Semester II

Sl. No	Course Type	Course Code	Course Title	Contact Hours/ Week		Credits
				L	P	
1	PSC-5	EE607	Detection and Estimation Theory	3	0	3
2	PSC-6	EE669	Deep Learning & Applications	3	0	3
3	PE-II	E2	Elective 2	3	0	3
4	PE-III	E3	Elective 3	3	0	3
5	PE-IV	E4	Elective 4	3	0	3
6	PSL/PSC/PE	EESL02	Signal Processing Laboratory II	3	6	3
7	PGC	PGC-602		2	0	2
			Total	17	6	20

* Four-week industrial practice school during summer vacation for scholarship students (optional)

Semester III

Sl. No	Course Type	Course Code	Course Title	Contact Hours /week	Credits
				P	
1	Dissertation & Seminar-Phase I	EE651	M. Tech. Dissertation Phase I	40	20
			Total	40	20

Semester IV

Sl. No	Course Type	Course Code	Course Title	Contact Hours /week	Credits
				P	
1	Dissertation & Seminar-Phase II	EE652	M. Tech. Dissertation Phase II	40	20
			Total	40	20

*1 Credit for Lecture/Tutorial means 1 contact hour in a week, and 1 credit for Practice/Dissertation means 2 contact hours in a week.

M. Tech. in Electronics and Communication Engineering
(Radar and Communication)

Semester I

Sl. No	Course Type	Course Code	Course Title	Contact Hours/ Week		Credits
				L	P	
1.	PSC-1	EE601	RF and Microwave Circuits	3	0	3
2.	PSC-2	EE602	Advanced Digital Signal Processing	3	0	3
3.	PSC-3	EE604	Radar System Design	3	0	3
4.	PSC-4	EE620	SoC and Embedded Systems	3	0	3
5.	PE-I	E1/EE667	Elective 1/Mobile and Satellite Communication	3	0	3
6.	PSL/PSC/PE	EERL01	R&C Laboratory I	0	6	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total	17	6	20

PSC: Program Specific Core; PSL: Program Specific Lab; PE: Professional Elective

Semester II

Sl. No	Course Type	Course Code	Course Title	Contact Hours/ Week		Credits
				L	P	
1	PSC-5	EE609	Antenna Systems	3	0	3
2	PSC-6	EE610	Radar Signal Processing	3	0	3
3	PE-II	E2	Elective 2	3	0	3
4	PE-III	E3	Elective 3	3	0	3
5	PE-IV	E4	Elective 4	3	0	3
6	PSL/PSC/PE	EERL02	R&C Laboratory II	3	6	3
7	PGC	PGC-602		2	0	2
			Total	17	6	20

* Four-week industrial practice school during summer vacation for scholarship students (optional)

Semester III

Sl. No	Course Type	Course Code	Course Title	Contact Hours /week	Credits
				P	
1	Dissertation & Seminar-Phase I	EE651	M. Tech. Dissertation Phase I	40	20
			Total	40	20

Semester IV

Sl. No	Course Type	Course Code	Course Title	Contact Hours /week	Credits
				P	
1	Dissertation & Seminar-Phase II	EE652	M. Tech. Dissertation Phase II	40	20
			Total	40	20

*1 Credit for Lecture/Tutorial means 1 contact hour in a week, and 1 credit for Practice/Dissertation means 2 contact hours in a week.

M. Tech. in Electronics and Communication Engineering
(Defence and Space Electronics)

Semester I

Sl. No	Course Type	Course Code	Course Title	Contact Hours/ Week		Credits
				L	P	
1.	PSC-1	EE601	RF and Microwave Circuits	3	0	3
2.	PSC-2	EE602	Advanced Digital Signal Processing	3	0	3
3.	PSC-3	EE604	Radar System Design	3	0	3
4.	PSC-4	EE654	Introduction to Space Technology	3	0	3
5.	PE-I	E1/EE667	Elective 1/Mobile and Satellite Communication	3	0	3
6.	PSL/PSC/PE	EEDL01	D&S Laboratory I	0	6	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total	17	6	20

PSC: Program Specific Core; PSL: Program Specific Lab; PE: Professional Elective

Semester II

Sl. No	Course Type	Course Code	Course Title	Contact Hours/ Week		Credits
				L	P	
1	PSC-5	EE609	Antenna Systems	3	0	3
2	PSC-6	EE614	EMI/EMC Design	3	0	3
3	PE-II	E2	Elective 2	3	0	3
4	PE-III	E3	Elective 3	3	0	3
5	PE-IV	E4	Elective 4	3	0	3
6	PSL/PSC/PE	EEDL02	D&S Laboratory II	3	6	3
7	PGC	PGC-602		2	0	2
			Total	17	6	20

* Four-week industrial practice school during summer vacation for scholarship students (optional)

Semester III

Sl. No	Course Type	Course Code	Course Title	Contact Hours /week	Credits
				P	
1	Dissertation & Seminar-Phase I	EE651	M. Tech. Dissertation Phase I	40	20
			Total	40	20

Semester IV

Sl. No	Course Type	Course Code	Course Title	Contact Hours /week	Credits
				P	
1	Dissertation & Seminar-Phase II	EE652	M. Tech. Dissertation Phase II	40	20
			Total	40	20

*1 Credit for Lecture/Tutorial means 1 contact hour in a week, and 1 credit for Practice/Dissertation means 2 contact hours in a week.

M. Tech. in Electronics and Communication Engineering
(VLSI and Embedded Systems)

Semester I

Sl. No	Course Type	Course Code	Course Title	Contact Hours/ Week		Credits
				L	P	
1.	PSC-1	EE620	SOC & Embedded systems	3	0	3
2.	PSC-2	EE621	Digital IC Design	3	0	3
3.	PSC-3	EE638	Mixed Signal IC Design	3	0	3
4.	PSC-4	EE673	Real-Time Operating Systems	3	0	3
5.	PE-I	E1/EE646	Elective 1/Artificial Intelligence for Embedded Systems	3	0	3
6.	PSL/PSC/PE	EEVL01	VLSI & ES Lab-01	0	6	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total	17	6	20

PSC: Program Specific Core; PSL: Program Specific Lab; PE: Professional Elective

Semester II

Sl. No	Course Type	Course Code	Course Title	Contact Hours/ Week		Credits
				L	P	
1	PSC-5	EE622	RFIC Design	3	0	3
2	PSC-6	EE637	ASIC Verification using System Verilog	3	0	3
3	PE-II	E2	Elective 2	3	0	3
4	PE-III	E3	Elective 3	3	0	3
5	PE-IV	E4	Elective 4	3	0	3
6	PSL/PSC/PE	EEVL02	VLSI & ES Lab-02	3	6	3
7	PGC	PGC-602		2	0	2
			Total	17	6	20

* Four-week industrial practice school during summer vacation for scholarship students (optional)

Semester III

Sl. No	Course Type	Course Code	Course Title	Contact Hours /week	Credits
				P	
1	Dissertation & Seminar-Phase I	EE651	M. Tech. Dissertation Phase I	40	20
			Total	40	20

Semester IV

Sl. No	Course Type	Course Code	Course Title	Contact Hours /week	Credits
				P	
1	Dissertation & Seminar-Phase II	EE652	M. Tech. Dissertation Phase II	40	20
			Total	40	20

*1 Credit for Lecture/Tutorial means 1 contact hour in a week, and 1 credit for practice/dissertation means 2 contact hours in a week.

M. Tech. in Electronics and Communication Engineering
(Semiconductor Chip Design)

Semester I

Sl. No	Course Type	Course Code	Course Title	Contact Hours/ Week		Credits
				L	P	
1.	PSC-1	EE621	Digital IC Design	3	0	3
2.	PSC-2	EE638	Mixed Signal IC Design	3	0	3
3.	PSC-3	EE620	SOC & Embedded Systems	3	0	3
4.	PSC-4	EE650	Semiconductor Devices for High-Speed and High-Power Applications	3	0	3
5.	PE-I	E1/EE655	Elective 1/IC Design: RTL to GDS implementation	3	0	3
6.	PSL/PSC/PE	EECL01	IC design Lab-I Device Design, FPGA & Front-End Design	0	6	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total	17	6	20

PSC: Program Specific Core; PSL: Program Specific Lab; PE: Professional Elective

Semester II

Sl. No	Course Type	Course Code	Course Title	Contact Hours/ Week		Credits
				L	P	
1	PSC-5	EE648	VLSI Fabrication Technology	3	0	3
2	PSC-6	EE656	IC Testing & Verification	3	0	3
3	PE-II	*E2	Elective 2	3	0	3
4	PE-III	*E3	Elective 3	3	0	3
5	PE-IV	E4	Elective 4	3	0	3
6	PSL/PSC/PE	*Lab	Laboratory	3	6	3
7	PGC	PGC-602		2	0	2
			Total	17	6	20

*Based on the elective course selection for E2, E3 & Lab from the **List of Electives-B**, the specialization stream will be from Analog & RF IC Design, Digital IC Design, and Microsystems Technologies verticals.

Semester III

Sl. No	Course Type	Course Code	Course Title	Contact Hours /week	Credits
				P	
1	Dissertation & Seminar-Phase I	EE651	M. Tech. Dissertation Phase I	40	20
			Total	40	20

Semester IV

Sl. No	Course Type	Course Code	Course Title	Contact Hours /week	Credits
				P	
1	Dissertation & Seminar-Phase II	EE652	M. Tech. Dissertation Phase II	40	20
			Total	40	20

*1 Credit for Lecture/Tutorial means 1 contact hour in a week, and 1 credit for practice/dissertation means 2 contact hours in a week.

List of Electives-A

Sl. No.	Course Code	Course Title	Contact hours/week		Credits
			L	T/P	
1	EE603	Wireless and Mobile Communication	3	0	3
2	EE605	Navigation System Concepts	3	0	3
3	EE606	Statistical Signal Processing	3	0	3
4	EE608	Modern Wireless Communications	3	0	3
5	EE611	Array Signal Processing	3	0	3
6	EE612	High Power Microwave Systems	3	0	3
7	EE613	Electronic Warfare	3	0	3
8	EE615	GNSS Receiver Design and Applications	3	0	3
9	EE616	Multi-Sensor Integrated Navigation	3	0	3
10	EE617	Inertial Navigation Systems	3	0	3
11	EE618	Indoor Navigation	3	0	3
12	EE619	Software Defined Radio	3	0	3
13	EE623	Semiconductor Devices	3	0	3
14	EE624	Digital System Design using FPGA	3	0	3
15	EE625	High-Performance DSP using FPGA	3	0	3
16	EE626	Compressed Sensing & Sparse Signal Processing	3	0	3
17	EE627	Signal Theory, Linear Algebra & Transform Techniques	3	0	3
18	EE628	Advanced Electronics Systems	3	0	3
19	EE629	Sonar Signal Processing	3	0	3
20	EE630	Sonar System Engineering	3	0	3
21	EE631	Satellite Communication	3	0	3
22	EE632	Advanced Communication Systems	3	0	3
23	EE633	Underwater Communications	3	0	3
24	EE634	Monolithic Microwave Integrated Circuit	3	0	3
25	EE635	Inertial Sensors and Systems	3	0	3
26	EE636	Navigation & Avionic Systems	3	0	3
27	EE639	Computer-Aided Design for VLSI Circuits	3	0	3
28	EE640	FPGA Architecture and Applications	3	0	3
29	EE641	VLSI Signal Processing	3	0	3
30	EE642	SoC Design and Verification	3	0	3
31	EE643	Digital Interface Design	3	0	3
32	EE644	MIMO Communications	3	0	3
33	EE645	Adaptive Signal Processing	3	0	3
34	EE646	Artificial Intelligence for Embedded Systems	3	0	3
36	EE647	RF Photonics	3	0	3
37	EE648	VLSI Fabrication Technology	3	0	3
38	EE649	Introduction to Electronics Systems	3	0	3
39	EE653	Quantum Transport in Nanoscale FETs	3	0	3
40	EE660	MEMS Sensors and Actuators	3	0	3
41	EE661	Microfabrication Techniques and Processes	3	0	3
42	EE666	Optical Space Communication	3	0	3
43	EE670	Time Frequency Analysis	3	0	3

44	EE672	Time Series Analysis and Forecasting	3	0	3

List of Electives-B

Course	Analog & RF IC Design Vertical	Digital IC Design Vertical	Microsystems Technologies Vertical
*E2	EE653: Quantum Transport in nanoscale FETs	EE637: ASIC Verification using System Verilog	EE659: MEMS and Microsystems Design
*E3	EE657: Low Power & High-Speed Analog Design,	EE665: Low power digital IC design	EE662: RF MEMS
E4	EE622: RFIC Design	EE658: Hardware Accelerators	EE663: MEMS Packaging/ EE664: MEMS Packaging and Reliability
*Lab	EECL02: IC design Lab-II: Mixed signal-RF IC & Back-End Design Lab	EECL03: IC design Lab-III: Advanced SoC-CAO & Back-End Design Lab	EECL04: MEMS Design Lab

A. Program Outcomes (POs)

PO1: An ability to independently carry out research /investigation, and development work to solve practical problems.

PO2: An ability to write and present a substantial technical report/document.

PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate post-graduate program.

B. Program Specific Outcomes (PSOs)

(a) M. Tech. in ECE with Signal Processing and Artificial Intelligence

PSO-1: Advanced Signal Processing Expertise

Apply advanced mathematical and algorithmic techniques to analyze, model, and process signals (audio, speech, image, video, biomedical, etc.) for solving real-world engineering problems.

PSO-2: Integration of AI in ECE Systems

Design and implement intelligent electronic and communication systems by integrating machine learning, deep learning, and data-driven techniques with classical signal processing frameworks.

PSO-3: Research and Innovation in SP & AI Applications

Demonstrate the ability to conduct independent research, develop innovative solutions, and apply modern tools for emerging applications in areas such as communication systems, IoT, robotics, healthcare, and multimedia.

(b) M. Tech. in ECE with Radar and Communication

PSO-1: Proficiency in Radar and Communication Systems

Demonstrate in-depth knowledge and technical expertise in the design, analysis, and implementation of advanced radar and communication systems for defense, aerospace, and civilian applications.

PSO-2: Radar Signal Processing and System Integration Skills

Apply advanced signal processing techniques and system integration skills for the development, testing, and optimization of radar signal processing, detection, estimation, and wireless communication systems.

PSO-3: Innovation and Research in Electromagnetics and RF Systems

Conduct research and develop innovative solutions in the fields of RF/microwave/Millimeter wave engineering, antenna design, propagation, and embedded systems for modern radar and high-speed communication technologies.

(c) M. Tech. in ECE with Defence and Space Electronics

PSO-1: Specialized Knowledge in Defence and Space Systems

Apply advanced principles of electronics and communication engineering to design, develop, and analyze systems used in defence and space applications, including Antenna systems, electronic warfare, satellite communication, navigation systems, and EMI/EMC.

PSO-2: Proficiency in Embedded, RF, and Secure Communication Technologies

Demonstrate the ability to develop embedded systems, RF/microwave circuits, and secure communication protocols for mission-critical defence and aerospace environments.

PSO-3: Innovation, Research, and System Integration for Strategic Applications

Undertake research and system-level integration to develop reliable, rugged, and high-performance electronic systems meeting the stringent requirements of defence and space sectors, in line with national strategic priorities.

(d) M. Tech. in ECE with VLSI and Embedded Systems

PSO-1: Expertise in VLSI Design and Verification

Apply advanced concepts of digital and analog VLSI design, CMOS technology, and hardware description languages (HDLs) to design, simulate, and verify complex integrated circuits for real-world applications.

PSO-2: Embedded System Design and Development

Design, program, and integrate embedded systems using microcontrollers, FPGAs, real-time operating systems (RTOS), and IoT platforms for industrial, consumer, and automotive solutions.

PSO-3: Research and Innovation in System-on-Chip (SoC) and Low-Power Design

Conduct research and develop innovative, high-performance, and energy-efficient SoC architectures and embedded solutions for emerging technologies in AI, communication, and automation.

(e) M. Tech. in ECE with Semiconductor Chip Design

PSO-1: Proficiency in Semiconductor Device and Chip Design

Apply advanced knowledge of semiconductor physics, device modeling, and fabrication processes to design and develop integrated circuits (ICs) and system-on-chip (SoC) solutions using industry-standard tools.

PSO-2: Expertise in Design, Verification, and EDA Tools

Demonstrate competence in front-end and back-end chip design, including RTL coding, synthesis, timing analysis, place-and-route, and verification using Electronic Design Automation (EDA) tools like Cadence, Synopsys, and Mentor Graphics.

PSO-3: Innovation and Research in Advanced Chip Technologies

Engage in research and development of high-performance, low-power, and scalable semiconductor solutions for applications in AI accelerators, high-speed communication, automotive electronics, and edge computing.

Detailed Contents

Course Code	Course Name	L – T – P	Credits
EE601	RF and Microwave Circuits	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Impart knowledge about Transmission lines. • Introduce the network analysis fundamentals • Enable the students to understand passive and active microwave circuits • Equip students with knowledge of measurement basics			
Course Contents Unit I: Introduction to EM Theory and Transmission Lines: Maxwell's equations, Electromagnetic waves, Characteristics of EM waves, Uniform plane waves, Boundary conditions, 3D and 2D transmission lines, Wave equation, Lossless transmission lines, Circuit model & Field analysis, Lossy transmission lines, TEM, TE, & TW wave solutions, Quarter-wave transformer, Relation between dB, dBm, and dBW. Unit II: Microwave Network Analysis: Impedance, Z & Y parameters, Scattering parameters, transmission (ABCD) matrix, Conversion, Discontinuities and Model analysis, Excitation of waveguides, Lumped elements, stub tuning, tapered lines. Unit III: Microwave Passive Devices and Circuits: Resonant circuits, Excitation of resonators, Cavity perturbations, Properties of Three port power dividers, Dividers & couplers, Wilkinson power dividers, Directional couplers, Quadrature (90°) Hybrid, Filters, Filter transformation, Filter implementation, Stepped-impedance low-pass filters, coupled line filters, Filters using coupled resonators, Coupled line directional couplers, Lange couplers, Phase Shifters. Unit IV: Microwave Active Devices and Circuits: Diode circuits, BJT- and FET-based circuits, Microwave integrated circuits, Microwave tubes, Oscillators, Frequency multiplier/mixers, Single-stage broadband transistor amplifier design, Power amplifiers, and LNAs. Unit V: Microwave Measurements: S-parameter measurements, Calibration standards, Vector Network analyzer, Spectrum analyzer, Phase noise measurement, Power measurement, Microwave subsystem, and system characteristics.			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Understand the fundamentals of Maxwell's equations and Transmission line theory CO2: Acquire knowledge of the various Two-port Parameters: Z-Matrix, Y-Matrix, ABCD-Matrix, S-Matrix CO3: Understand the basics of microwave passive components: Directional Couplers, Filters, Power dividers CO4: Design and develop microwave active circuits such as amplifiers, Oscillators, multipliers, etc. CO5: Hands-on with Microwave measuring equipment and understanding the measurement of microwave circuits			
Text Books			
1. David M. Pozar, Microwave Engineering, John Wiley, India. 2. Robert E. Collin, Foundations of Microwave Engineering, John Wiley, USA.			
Reference Books			

1. Reinhold Ludwig and G. Bogdanov, RF Circuit Design: Theory and Applications, Pearson Education, Asia.
2. S Y Lio, Microwave Devices and Circuits, Prentice Hall, India.
3. K. D. Prasad, Antenna and wave propagation, Satyaprakash Publications, New Delhi.
4. Electromagnetic, John D. Kraus, McGraw-Hill.

Course Code	Course Name	L – T – P	Credits
EE602	Advanced Digital Signal Processing	3-0-0	3

Course Objectives:

- Build strong foundations in linear algebra for applications in signal representation, transformations, and system analysis.
- Understand probability, random variables, and stochastic processes to model and analyze random signals and systems.
- Develop skills in real-time digital system design and implementation, considering finite word-length effects and computational efficiency.
- Apply various mathematical transforms (Fourier, Laplace, Z, Wavelet, etc.) for analysis and processing of signals.
- Design and implement analog and digital filters for practical signal processing applications.

Course Contents

Unit I: Introduction to Linear Algebra, Signals and Systems: Linear algebra: vector spaces, subspaces, linear independence, dimension, norms, orthogonal bases and Gram-Schmidt orthogonalization, linear transformation, Kernel and range, inverse transformations, matrices of linear transformations, change of basis, similarity, eigenvalues and eigenvectors, diagonalization, orthogonal diagonalization of symmetric matrices, singular value decomposition.

Unit II: Probability, Random Variable and Random Process: Randomness, axioms of probability, repeated trials, random variable, distribution, and density function, conditional distribution and density, moments, characteristic function, one random variable, two random variables, correlation, covariance, independence, orthogonality, stochastic process, mathematical description of random signals, Concept of a random process, stationarity, Ergodicity, autocorrelation function, cross-correlation function, power spectral density function, white noise.

Unit III: Real-Time Digital System Design and Implementation: Finite word length effects: fixed-point and floating-point number representations, truncation and rounding errors, quantization noise, coefficient quantization error, product quantization error, overflow error. Implementation: scalar operation, vector operation, matrix operation, complex number representation, and operation.

Unit IV: Transforms: Fourier series, Fourier transform, discrete time Fourier transform, discrete Fourier transform, Laplace transform, Z-transform, Wavelet Transform, Hilbert transform, and their properties and inverse transforms. FFT computations using decimation in time and decimation in frequency, the overlap-add and overlap-save method.

Unit V: Filters: Analog and digital filters, FIR filter design, IIR filter design, and realization using direct, cascade, and parallel forms, lattice structures.

Course Outcomes
On completion of this course, the students will be able to: CO1: Learn the basics of linear algebra, signals, and systems. CO2: Gain the theory of random variables, probability, and random processes. CO3: Acquire the basics of transforms such as the Fourier transform, the Laplace transform, and the Hilbert transform CO4: Learn the concept of analog and digital filters CO5: Gain knowledge of FIR & IIR Filters
Text Books/Reference Books
1. S.K. Mitra, Digital Signal Processing: A Computer Based approach, 3rd Ed., Tata McGraw Hill. 2. J. G. Proakis & D. G. Manolakis, Digital Signal Processing: Principles, Algorithms & Applications, 4th Ed., PHI. 3. Alan V Oppenheim & Ronald W Schaffer, Discrete Time Signal Processing, PHI. 4. Athanasios Papoulis, Probability, Random Variables, and Stochastic Processes, TATA McGraw Hill.

Course Code	Course Name	L – T – P	Credits
EE603	Wireless and Mobile Communication	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Build strong foundations in wireless and cellular communication. • Introduce Channel, BER, SER, and other performance parameters to assess the wireless link. • Enable the students to develop skills in coding and modulation • Understand mobile radio propagation • Design and implement RFID readers and tags			
Course Contents Unit I: Wireless Communications and Diversity: Introduction to Wireless Communication, Motivation, Types of Wireless Communication, Wireless Channel Modeling, Random Variable, Fading Channels, Linear Transformation, Bit Error Rate (BER) and Symbol Error rate (SER), BER and SER performance for Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), M-ary Pulse Amplitude Modulation (PAM) and M-ary PSK in Additive White Gaussian Noise (AWGN), Diversity Techniques, Issues in Wireless Communication. Unit II: Wireless Channel Modeling: Basics of Wireless Channel Modeling, Maximum Delay Spread, RMS Delay Spread, RMS delay based on power profile, Average Delay Spread in Outdoor Cellular Channels, Coherence Bandwidth in Wireless Communications, Inter symbol Interference (ISI), Doppler Fading in Wireless Systems, Doppler Impact on a Wireless Channel, Coherence Time of the Wireless Channel. Unit III: Cellular Communications: Introduction to Cellular Communications, Cell Capacity and Frequency reuse, Coverage Improvement, Multiple Access Technologies, Cellular Processes Call Setup, Handover, Teletraffic Theory, Equalization and Diversity			

Techniques, Modulation and Coding Techniques for Mobile Communication, GSM, CDMA, 4G, VOLTE and 5 G technologies, Introduction to Wireless OFDM – OFDM principles, system model – Generation of sub carrier using IFFT, windowing, choice of OFDM parameters, OFDM signal processing. Unit IV: Mobile Radio Propagation: Introduction to Mobile Radio Propagation, Reflection, Diffraction, Scattering, Propagation Models, Doppler Effect, Delay Spread, Ultra-Wideband Communication System, Fading, TDM, FDM, TDMA, FDMA, CDMA, OFDM. Unit V: Near-field Wireless Communications: Introduction to RFID System, RFID Reader and Tag Design, Compact RFID Readers, Propagation Channel, Conventional and Unconventional Applications of RFID, Link Budget, Multipath and Ground Reflections Localization, RFID Standards, Specific Absorption Rate, Chip less RFID, NFC.			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Understanding of the basics of wireless communication, basic terms such as Bit error rate, symbol error rate, etc., and advantages and disadvantages of different wireless communication techniques. CO2: Grasp the basics of wireless channel modeling, Inter-symbol interference, and Doppler fading. CO3: Learn cellular communication, frequency reuse, handover, and various multiple access techniques. CO4: Acquire knowledge of multiple access techniques, understanding of phenomena such as reflection, refraction, scattering, and diffraction. CO5: Learn the basics of RFID, propagation channel in RFID, and various near-field and far-field wireless techniques.			
Text Books/Reference Books			
1. Fundamentals of Wireless Communications – David Tse and Pramod Viswanath, Publisher Cambridge University Press. 2. Wireless Communications: Andrea Goldsmith, Cambridge University Press. 3. Wireless Communications: Principles and Practice –Theodore Rapp port Prentice Hall. 4. MIMO Wireless Communications – Ezio Biglieri – Cambridge University Press. A joint venture by IISc and IIT 5. Introduction to Space Time Wireless Communications – Arogyaswami Paulraj – Cambridge University Press. 6. Digital Communications – John G Proakis – McGraw Hill Science/Engineering/Math. 7. Wireless Communications – Andreas Molisch – Wiley IEEE Press. 8. Mobile Wireless Communications – Mischa Schwartz – Cambridge University Press.			

Course Code	Course Name	L – T – P	Credits
EE604	Radar System Design	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Impart knowledge about various types of Radars and their working. • Introduce the performance parameters of Radar.			

- Impart the knowledge of the application of Radar.
- Provide practical knowledge of the design of Radar.

Course Contents

Unit I: Introduction to Radar: Basic principles of radar, Frequencies of operation, Classification of radars, their functionality and applications, Types of radar: CW, FMCW, Pulse Doppler, Radar Range Equation, Cross Range and Doppler/Velocity measurements and Resolutions, Peak power, Average power, and Duty Cycle, Target, Noise Power, and Noise Power density, False Alarm, Concept of Detection, Losses in Radar Equation, Signal Integration and Processing Gain, Radar Equation for Bistatic, Search and Tracking Radars, Equation for Beacon, Cover Up and Self Protection Jamming.

Unit II: Radar Cross Section (RCS), Clutter & Theory of Detection: Probability of Detection P_d , Probability of False Alarm PFA and Relation between P_d , Pfa, and SNR—statistical phenomenon of Noise. Target characteristics— RCS, RCS fluctuation, Swirling Models, SNR deviation for fluctuating targets, Ground/Surface, Sea clutter, Radar Equation for low Grazing Angle, Volume clutter – Rain, birds, chaff, Clutter discrete, Clutter characteristics of airborne radar – Clutter limited operation Vs Noise limited operation of radar, Losses.

Unit III: Tracking radar & Propagation: Concept of Tracking, Conical Scan Angle Tracking, Lobing Angle Tracking, Monopulse Tracking; Amplitude and Phase Comparison, Wideband Monopulse Tracking, Conventional 2D Surveillance radar: Battlefield Surveillance Radar, Coastal Surveillance radars, AESA radars, and Airborne Radars, Layers of the Atmosphere and Ray Travel, Interference and Diffraction Region, Refraction of EM Waves, Effective Earth Model, Anomalous Propagation, Ionosphere Refraction and Attenuation.

Unit IV: Radar Transmitter & Antenna Design: Functions of Radar Transmitters, Transmitter Features, Transmitter Sub-Systems, Active Device for Different Frequency Bands, Tube Transmitters, Solid State Transmitters, Concept of Distributed Transmitters, Function and Features of Radar Antenna, Types of Antennae, Phased Array Antenna, Antenna Elements, Architectures for phased array, Antenna-based architecture, Bandwidth-based architecture, function-based radar, electronic/mechanical steering phased array, Phase shifters, and radiators, frequency scan array, beam agility, Interleaving of detection, Frame time, Radar Scheduling- Algorithms for scheduling.

Unit V: Duplexer/TR Switch & Radar Receiver: Function and Characteristics, Types of Duplexers, Radar Receiver Characteristics, Receiver Parameters, Receiver Architectures, Digital Receiver, modern radar concepts - Synthetic Aperture Radar principle, the SAR characteristics like cross range, aperture, Doppler, chirp, SAR modes: strip map, spotlight, Doppler beam sharpening, Inverse SAR, Advancements in Pulsed and CW radars, ECCM techniques.

Course Outcomes

On completion of this course, the students will be able to

CO1: Analyze, design, and develop RADAR transmitter, receiver, and Antenna. CO2: Learn formulated RADAR equations for various types of RADARs (Bi-static, surveillance, and static) and also understands the concepts of jamming. CO3: Acquire knowledge of RADAR cross section, clutter, atmospheric propagation, and probability of false detection CO4: Apply knowledge and skills to design a RADAR transmitter and receiver. CO5: Apply skills to simulate a moving target RADARs, Measurement of Doppler shift, and other real-time situations.
Text Books
1. Mark A. Richards, Principles of Modern Radar: Basic Principles, Yes Dee Publishing Pvt., Ltd. 2. M.I. Skolnik, Introduction to Radar Systems, Tata MG Hill. 3. T.W. Jeffrey Phased-Array Radar Design, Scitech Publishing. 4. I.G. Cumming, Digital Processing of Synthetic Aperture Radar Data: Algorithms and Implementations, Artech House.
Reference Books
1. B.R. Mahafza, Radar System Analysis and Design Using, CRC press. 2. Peyton Z. Peebles, Radar Principles, Wiley. 3. Harold R. Raemer, Radar Systems Principles, CRC press. 4. George W. Stimson, Introduction to Airborne Radar, Scitech Publishing.

Course Code	Course Name	L – T – P	Credits
EE605	Navigation Systems Concepts	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the basics of navigation • Know the GNSS fundamentals. • Impart the knowledge of inertial navigation. • Provide practical knowledge of Satellite Navigation Processing, Errors, and Geometry.			

Course Contents

Unit I: Introduction to Navigation: Navigation, Position Fixing, Dead Reckoning, Inertial Navigation, Radio and Satellite Navigation, Terrestrial Radio Navigation, Satellite Navigation, Feature Matching, The Complete Navigation System, Navigation Mathematics: Coordinate Frames, Kinematics, and the Earth: Coordinate Frames, Kinematics, Earth Surface and Gravity Models, Frame Transformations, Orbital Mechanics.

Unit II: GNSS: Fundamentals, Signals, and Satellites: Fundamentals of Satellite Navigation, The Systems: Global Positioning System, GLONASS, Galileo, Beidou, IRNSS, GNSS, Interoperability: Frequency Compatibility, User Competition, Multistandard User Equipment Augmentation Systems, System Compatibility, GNSS Signals, Navigation Data Messages, Comparison between GNSS, GPS, Galileo and other Nav Systems.

Unit III: Inertial Navigation: Inertial-Frame Navigation Equations, Earth-Frame Navigation Equations, Local-Frame Navigation Equations, Navigation Equations Precision, Initialization and Alignment, INS Error Propagation, Platform INS, Horizontal Plane Inertial Navigation, types of GYROs: Mechanical, Ring Laser and Fiber Optic, Accelerometers.

Unit IV: Advanced Satellite and Terrestrial Navigation: Differential GNSS, Carrier-Phase Positioning and Attitude, Poor Signal-to-Noise Environments, Multipath Mitigation, Signal Monitoring, Semi-Codeless Tracking, Instrument Landing System, Receiver Hardware and Antenna, Relative Navigation, Tracking and Positioning, Ultra-wideband, Short-Range Communications Systems.

Unit V: Satellite Navigation Processing, Errors, and Geometry: Satellite Navigation Geometry, Ranging Processor, Range Error Sources, Navigation Processor, Attitude Measurement, Height and Depth Measurement, Barometric Altimeter, Depth Pressure Sensor, Radar Altimeter, Odometers, Pedestrian Dead Reckoning.

Course Outcomes

On completion of this course, the students will be able to:

CO1: Learn the basics of navigation, position fixing, radio and satellite navigation, terrestrial radio navigation, understanding of coordinate frames, kinematics, earth surface, and gravity models.

CO2: Understand of satellite navigation, global positioning system, GNSS, and a detailed comparison between various navigation systems.

CO3: Pick up the basic understanding of Multipath Mitigation, Signal Monitoring, Semi-Codeless Tracking, Radio Positioning Configurations, and Methods.

CO4: Learn the basics of Aircraft Navigation Systems, Error Sources, Differential Loran, Ultra-wideband, Short-Range Communications Systems, Other Positioning Technologies, Receiver Hardware, and Antenna.

CO5: Gain knowledge of Attitude Measurement, Height and Depth Measurement, Other Dead-Reckoning Techniques, Sequential Processing, Laser TRN, Barometric TRN, Sonar TRN, Stellar Navigation, Magnetic Field Variation, and Measurement Models.

Text Books/Reference Books

1. Paul D. Groves, Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Artech House, 2008 and 2013 Second Edition.
2. Esmat Bekir, Introduction to Modern Navigation Systems, World Scientific Publishing Co Pte Ltd, 2007.
3. B. Hofmann Wollenhof, H. Lichtenegger, and J. Collins, GPS Theory and Practice, Springer Wien, New York, 2000.

4. Pratap Misra and Per Enge, "Global Positioning System Signals, Measurements, and Performance," Ganga-Jamuna Press, Massachusetts, 2001.
5. Ahmed El-Rabbany, Introduction to GPS, Artech House, Boston, 2002.
6. Bradford W. Parkinson and James J. Spilker, Global Positioning System: Theory and Applications, Volume II, American Institute of Aeronautics and Astronautics, Inc., Washington, 1996.

Course Code	Course Name	L – T – P	Credits
EE606	Statistical Signal Processing	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand signal characterization and LTI system analysis, including sampling, DFT-based filtering, and cepstrum techniques. • Apply linear prediction and optimum filtering methods for modeling stationary random processes and spectral estimation. • Develop and implement least-squares and adaptive filtering techniques for system identification, prediction, and noise reduction. • Analyze nonstationary signals using time–frequency methods, including STFT, spectrograms, and quadratic time–frequency distributions. • Utilize wavelet transforms and filter banks for advanced signal analysis, noise suppression, and classification applications.			
Course Contents Unit I: Introduction: Characterization of Signals, Characterization of Linear Time-Invariant Systems, Sampling of Signals. Linear Filtering Methods Based on the DFT, the Cepstrum, Summary and References, Problems. Unit II: Linear Prediction and Optimum Linear Filters: Innovations Representation of a Stationary Random Process, Rational power spectra, Forward and Backward Linear Prediction, Solution of the Normal Equations, Properties of the Linear Prediction-Error Filters, AR Lattice and ARMA Lattice-Ladder Filters. Unit III: Least-Squares Methods and Filter Design: System Modeling and Identification, Least Squares Filter Design for Prediction and Deconvolution, Solution of Least-Squares Estimation Problems, Adaptive Filters, Adaptive Direct-Form FIR Filters, Adaptive Lattice-Ladder Filters, Wiener Filters for Filtering and Prediction. Unit IV: Time Frequency Analysis: Time-Frequency Distributions: Fundamental Ideas, Global average, local average, shift invariance, Uncertainty Principle and Joint distribution, Short-Time Fourier Transform and Spectrogram, Wigner-Ville Distribution, Time-Varying Power Spectral Density Distribution, Filtered Function of Time, Instantaneous Power Spectra, Quadratic TFDs, Time-Varying Power Spectra of Nonstationary Random Processes. Unit V: Wavelet Transform for Signal Analysis: Continuous wavelet transforms, Wavelet bases. Balian-Low theorem. Classes of wavelets: Haar, Daubechies, and bi-orthogonal. Discrete Wavelet Transform and Filter Banks. Orthogonal and biorthogonal two-channel filter banks, Design of two-channel filter banks. Wavelet methods for signal processing. Noise suppression. Representation of noise-corrupted signals using frames. Algorithm for			

reconstruction from corrupted frame representation. Audio classification. Gabor Wavelets for statistical signal processing.
Course Outcomes
On completion of this course, the students will be able to: CO1: Generalize the properties of statistical models in the analysis of signals using Stochastic processes. Students will learn the forward and backward linear prediction for filter design. CO2: Learn the last-square methods for filter design. CO3: Acquire the basics of adaptive filters, time-frequency analysis, and the Wavelet transform. CO4: Applying knowledge and skills to visualize different types of data/signals in the time domain, frequency domain, and time-frequency domain. CO5: Acquire knowledge of statistical models and feature extraction.
Text Books
1. Algorithms for Statistical Signal Processing, John G. Proakis. 2. Probability & Random Processes with Applications to Signal Processing, 2001, 3Edn. Henry Stark and John W Woods, Prentice Hall 3. Adaptive Signal Processing Bernard Widrow, Samuel D. Stearns. 4. Time Frequency Analysis, 1995 by L. Cohen, Prentice Hall PTR. 5. A Wavelet Tour of Signal Processing, 2nd edition, S. Mallat, Academic Press, 1999.
Reference Books
1. Optimum signal processing: An introduction - Sophocles.J.Orfamadis, 2 ed., 1988, McGraw-Hill, Newyork 2. Adaptive signal processing-Theory and Applications, S.Thomas Alexander, 1986, Springer –Verlag. 3. Signal analysis – Candy, Mc Graw Hill Int. Student Edition 4. James V. Candy, Signal Processing: A Modern Approach, McGraw-Hill, International Edition, 1988. 5. Multiresolution and Multirate Signal Processing: Introduction, Principles and Applications - V.M. Gadre, A.S. Abhyankar, 2016, Mc Graw Hill Education (India) Private Limited.

Course Code	Course Name	L – T – P	Credits
EE607	Detection and Estimation Theory	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Strengthen understanding of vector spaces and matrix theory, including PCA and SVD, for signal representation and dimensionality reduction. • Analyze and model stochastic processes and their behavior through LTI systems, including cyclostationary processes and spectral analysis. • Apply detection theory for signal identification in noise using statistical decision-making principles and optimal detectors.			

• Develop estimation techniques using minimum variance methods, Cramer–Rao bounds, and system identification approaches. • Implement Wiener and Kalman filtering methods for optimal signal estimation and tracking in discrete-time systems.
Course Contents Unit I: Review of Vector Spaces: Vectors and matrices: notation and properties, orthogonality and linear independence, bases, distance properties, matrix operations, eigenvalues, and eigenvectors. Diagonalization of symmetric matrices, symmetric positive definite and semi-definite matrices, principal component analysis (PCA), and singular value decomposition. Unit II: Stochastic Processes: Time average and moments, ergodicity, power spectral density, covariance matrices, response of LTI system to random process, cyclostationary process, and spectral factorization. Unit III: Detection Theory: Detection in white Gaussian noise, correlator, and matched filter interpretation, Binary hypothesis testing, Neyman-Pearson theorem, Likelihood ratio test, Deflection coefficient, Receiver operating characteristic, Bayes' criterion of signal detection, Maximum likelihood detector, MAP, LMS, entropy detectors, detection in colored Gaussian noise, Karhunen-Loeve expansions and whitening filters. Unit IV: Estimation Theory: Minimum variance estimators, Cramer-Rao lower bound, examples of linear models, system identification, Markov classification, clustering algorithms. Unit V: Topics in Kalman and Wiener Filtering: Discrete time Wiener-Hopf equation, error variance computation, causal discrete time Wiener filter, discrete Kalman filter, extended Kalman filter, examples.
Course Outcomes On completion of this course, the students will be able to: CO1: Learn the basics of vectors, matrices, basis functions, orthogonality, SVD, EVD, SSA, PCA. Moreover, the concept of ergodicity, PSD, covariance matrices, response of LTI system to a random process, and spectral factorization are grasped. CO2: Learn the concepts of the least-square methods for filter design, detection in the noisy case, correlator and matched filter, Hypothesis testing, N-P theorem, Likelihood ratio test, Deflection coefficient, Receiver operating characteristic, Bayes' criterion of signal detection, ML detector, MAP, LMS, and entropy detectors. CO3: Learn the basics of minimum variance estimators, CR lower bound, linear models, system identification, Markov classification, and clustering algorithms, basics of Wiener-Hopf equation, error variance computation, causal Wiener filter, and Kalman filter are given to students. CO4: Apply knowledge and skills to visualize different types of data/signals in the time domain, frequency domain, and time-frequency domain. They are capable of designing various types of filters. CO5: Acquire knowledge of designing Kalman and Wiener filters
Text Books/Reference Books 1. Fundamentals of statistical signal processing, vol. 1 and 2, S M Kay, Prentice Hall, 1998 2. Linear Estimation, Kailath, Sayed, and Hassibi, Prentice Hall, 2000.

3. An Introduction to Signal Detection and Estimation, H. Vincent Poor, 2nd Edition, Springer, 1998.

Course Code	Course Name	L – T – P	Credits
EE608	Modern Wireless Communications	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Understand the basics of advanced wireless schemes
- Understand the concept of MIMO
- Impart the knowledge of OFDM
- Know about the wireless standards

Course Contents

Unit I: Introduction to Wireless Communications: Motivation, Applications of Wireless Communication, Multipath Propagation, Wireless Channel Modeling, Fading Nature of the Wireless Channel, Probability Density Function of Amplitude and Phase, Deep Fade Phenomenon in Wireless Channels, Optimal Receiver Combining, SNR Performance, BER Performance with Diversity – Analysis, Diversity in Wireless Systems, Diversity Order, Types of Diversity, Antenna Spacing Requirement, Deep Fade Analysis with Diversity, Autocorrelation Function.

Unit II: Multiple Input Multiple Output (MIMO): Introduction to MIMO, MIMO System Model, MIMO Zero-Forcing and Minimum Mean Square Error (MMSE) Receivers, Introduction to Singular Value Decomposition (SVD), Examples of SVD and Eigenmodes of the MIMO Channel, MIMO Channel Capacity, MIMO Diversity – Alamouti, Orthogonal Spacetime Block Codes (OSTBC), MIMO Beamforming.

Unit III: OFDM: Introduction to OFDM, Multicarrier basics, Multicarrier transmission, Modulation and Cyclic Prefix in OFDM, impact of cyclic prefix in data rate, Bit-error rate for OFDM, Effect of frequency offset issue in OFDM, OFDM– Peak-to-Average Power Ratio (PAPR), SNR performance, MIMO-OFDM.

Unit IV: New Wireless Technology: Introduction to 5G Wireless Technologies, Massive Multiple Input Multiple Output, mm Wave, Non-orthogonal Multiple Access (NOMA), Filter Bank Multi Carrier (FBMC) Technique, and Full Duplex.

Unit V: Wireless Standards: IEEE 802.11 Wireless Standards, Comparison of IEEE 802.11 Wireless Standards, Wi-Fi, Bluetooth, Wireless Local Area Network (WLAN), Introduction to Long-Term Evolution (LTE), Introduction to Worldwide Interoperability for microwave Access (WiMAX), LTE-TDD and LTE-FDD, Frequency Bands and Technology Specs.

Course Outcomes

On completion of this course, the students will be able to:

CO1: Acquire knowledge of modern wireless communication systems, understanding basic terms such as signal-to-noise ratio, diversity, fading, etc.

CO2: Learn MIMO, Singular Value Decomposition, and beamforming.

CO3: Gain knowledge of OFDM, OFDM-MIMO, and modulation techniques.

CO4: Develop understanding of new wireless technologies such as 5G, NOMA, FBMC, Massive MIMO, etc. CO5: Acquire knowledge of various wireless standards.
Text Books/Reference Books
1. Andrea Goldsmith, Wireless Communication, Cambridge University Press, The Edinburgh Building, Cambridge, UK. 2. Tse, David and Viswanath, Pramod, Fundamentals of Wireless Communication, Cambridge University Press (2004). 3. Aditya Jagannatham, Principles of Modern Wireless Communication Systems, McGraw Hill, (2016) 4. Theodore Rappaport, Wireless Communications, principles and Practices, 2nd Edition, Pearson. 5. P. W. Wolniansky, G. J. Foschini, G. D. Golden, R. A. Valenzuela “V-BLAST: An Architecture for Realizing Very High Data Rates Over the Rich-Scattering Wireless Channel”, Bell Labs Report, 1998. 6. Marco Di Renzo et. al, “Spatial Modulation for Generalized MIMO: Challenges, Opportunities and Implementation”, Vol. 102, No.1, 2014.

Course Code	Course Name	L – T – P	Credits
EE609	Antenna Systems	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Grasp basics of EM radiation and conventional antennas. • Provide knowledge of Antenna arrays and beam forming. • Grasp the basics of planar antennas of various configurations. • Design and develop various types of aperture antennas • Learn characterization of the antenna with the help of microwave measuring equipment.			
PRE-REQUISITE: Introduction: Definition, Types, and Parameters of Antennas, Definition of Parameter: Radiation Patterns-Fields (E&H), Concept of Near and Far Fields, Solid Angle, Beam Width, Radiation Efficiency, Radiation Intensity, Directivity, Gain, Efficiency, Input Impedance, Radiation Resistance, Bandwidth, Circular Polarization, Antenna Noise Temperatures, Power Handling Capability: Voltage and Current Breakdown, Weathering Effect on Antennas.			
Course Contents Unit I: Basics of Radiation Mechanism: Concept of Electric and Magnetic Current Distribution of Antennas, Vector and Scalar Potentials (Electrical and Magnetic), Derivation of Radiation Patterns for Ideal, Small and Half Wavelength Dipole Antennas, Monopole, Loop, Yagi-Uda, Design of dipole and monopole antenna. Unit II: Antenna Arrays: Analysis & Synthesis: Principles of Antenna Array: N element linear arrays – uniform amplitude and spacing, Directivity of Broadside and End fire arrays, Half Power Beam Width, Main lobe, Nulls, Side lobes, Inter-element spacing, Pattern multiplication, electronic scanning, Mutual Coupling, Grating lobes, Planar Arrays: array			

grid (Rectangular & Triangular), Selection of radiating elements for electronic scanning, scan loss, active impedance, scan blindness, Array Synthesis for beam formation: Binomial, Dolph-Tchebycheff, and Taylor distribution arrays. Unit III: Planar/ Patch Antennas: Microstrip Antennas (MSAs): Principle of radiation of Rectangular Microstrip Antenna, Feeding Techniques of MSAs, E & H field, RLC model, basic design equation, impedance, and beam width characteristics, Circular and Triangular MSAs, Compact Microstrip Antennas, Broadbanding techniques. Printed Dipole and Monopoles – principles and broadbanding techniques. Design a Rectangular, Circular and Triangular Patch Antennas. Unit IV: Aperture and Travelling Wave Antennas: Babinet–Brookner Theorem, Slot Antennas, Horn Antennas: E-plane Sectoral Horn, H-plane Sectoral Horn, Pyramidal Horn, Conical Horn, Aperture Matched Horn, Corrugated Horn, Broadband Horn Antenna, Reflector Antennas- Planar, Angular and Curved Reflector Antennas: Parabolic Reflector; Front feed, Cassegrain –feed and Gregorian- feed, Spherical Reflector, Design of a Pyramidal and Conical Horn Antenna, Concept of Frequency Independent and Travelling Wave Antennas, Self-Complementary Antennas, Biconical Antenna, Log Periodical Antennas, Helical Antennas: Normal and Axial Mode, Spiral Antennas. Unit V: Antenna Measurements: Input impedance, Return Loss, VSWR, Bandwidth, Polarization, Radiation Patterns, Beam Width, Gain, etc.			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Understand the basics of EM radiation and conventional antennas. CO2: Design and synthesis of Antenna arrays and beam forming. CO3: Design of planar antennas of various configurations. CO4: Understand various types of aperture antennas CO5: Learn how to characterize the antenna with the help of microwave measuring equipment.			
Text Books			
1. Constantine A. Balanis, Antenna Theory: Analysis and Design, John Wiley & Sons, 2005. 2. Richard Poisel, Search Results Antenna Systems and Electronic Warfare Applications, Artech House. 3. Vijay Madiseti, Wireless, Networking, Radar, Sensor Array Processing, and Nonlinear signal processing, CRC press.... 4. Kai Chang, RF and Microwave Wireless Systems, Wiley series.			
Reference Books			
1. Mike Golio, Janet RF and Microwave Passive and Active Technologies, CRC press. 2. Frank Gustrau, RF and Microwave Engineering, Wiley.			

Course Code	Course Name	L – T – P	Credits
EE610	Radar Signal Processing	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Impart knowledge about Radar Signal Processing.
- Introduce processing schemes of Radar.
- Impart the knowledge of algorithms of Tracking Radar.
- Provide practical knowledge of modern Radar.

Course Contents

Unit I: Radar signal processing chain: Introduction, Radar receiver chain, derivation of Doppler frequency shift, N-pulse DLC, Moving Target Indicator (MTI), Optimum MTIs, Improvement Factor, Coherent Pulse integration – FFT, FIR filters, Concept of Constant False Alarm Rate (CFAR), CFARs for various scenarios, Clutter map CFAR, site adaptive Radar signal processing, Radar displays, convolutional models in range and angle, frequency domain models, Doppler processing, Matched filter (vector formulation), MTI and matched filter approximation.

Unit II: Pulse compression and micro-doppler processing: Radar modulation techniques, FMCW waveforms, Nonlinear FM, Stepped LFM, SFCW Radar, multi-frequency Radar, Bi-phase, poly-phase codes, Stretch Processing, Matched Filtering, Ambiguity diagram, Micro-Doppler effect - Phenomenon and application, modeling, and simulation.

Unit III: Tracking algorithms: Kalman Filters, Manouever Detection, Adaptive Kalman Filter, Interactive Multiple Model (IMM), Kalman Filter Track Initiation, False Track handling, Track Quality Tracking in Clutter, Data Association, Probabilistic Data Association, Multi-Target Tracking, Multiple Hypothesis Tracking on moving Platform, Tracking with Phased Array Radars, Performance Measures, Multi-Radar Tracking Schemes.

Unit IV: Data processing for phased array radar: Introduction, analog and digital beam forming, verification and Tracking, multi-target tracking, high precision tracking, adaptive array processing, Introduction to photonics Radar. Introduction, General array, linear array, Adaptive array processing, Non-linear beam forming (LMS, ALMS), sidelobe cancellers. Spatial filtering beam forming.

Unit V: SAR/ISAR imaging algorithms: Signal Processing, Waveform design – LPRF, MPRF, HPRF, and Platform Motion Compensation. Advanced Processing for Airborne Radars – Space Time Adaptive Processing, Principles, GLRT, AMF, Reduced Rank and Reduced Data STAP. Geometry of imaging radar, Doppler frequency and radar image processing, spherical wave front vs. planar wave front, quadratic phase Errors, Polar Format Algorithm, Range Migration Algorithm, Platform Motion Compensation, Future Growth of Modern Radar: UWB radar, Knowledge-based radar, Cognitive radar.

Course Outcomes

On completion of this course, the students will be able to:

CO1: Gain Knowledge on Mathematical interpretation & operation in Signals, Radar receiver & its components, DLC & its application & limitation, MTI & matched filter approximation.

CO2: Understand the fundamentals of Pulse compression requirements and its techniques. Radar based on pulse compression CO3: Know the basics of tracking algorithms & their components & their limitations & advancements in technology. Different Tracking Schemes CO4: Know the basics of Beam forming for different types of targets. Need for Photonic Radar and Its Components and Applications. CO5: Exposure to Signals & waveform techniques, need for airborne radar, understand the significance of Doppler frequency in radar applications, introduction to arrays & their advancement.	
Text Books	
1. Mark A. Richards, Fundamentals of radar signal processing, Tata McGraw-Hill. 2. Eyung W. Kang, Radar systems: analysis, design and simulation, Artech house. 3. B.R. Mahafza, Radar Signal Analysis and Processing using MATLAB, CRC Press. 4. George W. Stimson, Introduction to Airborne Radar, Scitech Publishing. 5. Ian G. Cumming and Frank H. Wong, Digital processing of synthetic aperture radar, Artech House	
Reference Books	
1. D. Curtis Schleher, MTI and Pulsed Doppler radar with MATLAB, Artech House. 2. Peyton Z. Peebles, Radar Principles, Wiley. 3. A. Farina, Radar Data Processing, John Wiley & Sons. 4. Bu-Chin Wang, Digital Signal Processing Techniques and Applications in Radar Image processing, Wiley.	

Course Code	Course Name	L – T – P	Credits
EE611	Array Signal Processing	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Impart knowledge about Spatial Signals. • Introduce different array configurations. • Impart the knowledge of beamforming. • Provide practical knowledge of algorithms for Array processing.			
Course Contents			

Unit I: Spatial signals: Array processing fundamentals, signals in space and time, spatial frequency, frequency wave number, direction vs. frequency, beam pattern, wave front, far field and near field, spatial sampling, Nyquist criterion, aliasing in spatial frequency domain, sensor arrays, spatial domain filtering, spatial DFT/FFT. Unit II: Sensor arrays: Uniform linear arrays, electronic steering, array performance measures, non-isotropic element pattern, tapering, null steering, non-uniform linear arrays, beam space processing, planar and volumetric arrays, wideband arrays. Unit III: Beamforming-1: Time delay beamforming, frequency domain beamforming, optimum beamformers: MVDR, MPDR, MMSE, Max SNR, LCMV, LCMP, GSC, Unit IV: Beamforming-2: mismatched beam former, eigenvector beamformer, beam space beamformer, broadband beamformer, adaptive beam formers: LMS and RLS. Unit V: Direction of arrival estimation: DoA estimation: ML, MAP, MUSIC, ESPRIT, for uncorrelated, correlated, and coherent signals.			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Learn the basics of the principle of spatial signals: Array processing fundamentals, signals in space and time. CO2: Get the concepts of sensor arrays and Uniform linear arrays. CO3: Learn the basics of beamforming-related concepts. CO4 Apply knowledge and skills to understand the direction of arrival methods. CO5: Acquire the knowledge of MUSIC and ESPRIT.			
Text Books			
1. H.L. Van Trees, “Optimum Array Processing, Part 4 of Detection, Estimation and Modulation Theory, John Wiley & Sons, 2002. 2. Adaptive signal processing Bernard Widrow, Samuel D. Stearns. 3. A Mathematical Introduction to Compressive Sensing, Simon Foucart, Holger Rauhut, Springer New York. 4. Compressed Sensing: Theory and Applications, Yonina C. Elda, Cambridge University Press.			

Course Code	Course Name	L – T – P	Credits

EE612	High Power Microwave Systems	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Impart knowledge about HPM Systems. • Introduce MW Basics. • Impart the HPM Technologies. • Provide practical applications of HPM.			
Course Contents Unit I: Introduction and Design of HPMW Systems: Introduction, HPM operating regimes, future directions in HPM, system approach, components linking, system issues, and advanced systems. Unit II: MW Fundamentals: Introduction, Basic concepts in EMs, Periodic slow-wave structures, cavities, intense relativistic electron beam, rotating magnetically insulated electron layers, microwave-generating interactions, amplifiers and oscillators, high and low current operating regimes, and multispectral sources. Unit III: HPM Technologies: Introduction, pulse power, electron beam generation/propagation, pulse compression, diagnostics, computational technology, HPM facilities, beamless systems, UWB switching technologies, UWB systems, and non-linear transmission lines. Unit IV: HPM sources and structures: Introduction, design principles, operational features, R&D issues: Relativistic magnetrons, MILOs, BWOs, MWCGs and O-type Cerenkov devices, Klystrons and Reltrons, Vircators, Gyrotrons, Electron Cyclotron masers and free-electron lasers. Unit V: HPM APPLICATIONS: HPM weapons, EM terrorism, counter DEW, High-power radar, power beaming, space propulsion, plasma heating, and particle accelerators.			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Acquire knowledge of High-Power Microwave Systems and Microwave Fundamental Concepts. CO2: Learn technological advancements in HPM and Microwave. CO3: Gain knowledge of HPM Generation-related Structures and Their Studies. CO4: Learn HPM sources and facilities. CO5: Apply knowledge in HPM technologies in various areas.			
Text Books/Reference Books			
1. James Benford, John A. Swegle, and Ed Schamiloglu, High Power Microwave, CRC Press			

2. Adaptive signal processing Bernard Widrow, Samuel D. Stearns.
3. Victor L. Granatstein, Igor Alexeff, High-power Microwave Sources, Artech House.
4. R. A Cairns, A. D. R. Phelps, Generation and Application of High-Power Microwaves, CRC Press.

Course Code	Course Name	L – T – P	Credits
EE613	Electronic Warfare	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Understand electronic defence, intercept system characteristics, and functions.
- Acquire knowledge of crystal video receiver, IFM receiver, superheterodyne receiver, channelized receiver, and Bragg cell receiver.
- Understand various types of jamming and ECM techniques.
- Understand Search radar counter-countermeasures and tracking radar counter-countermeasures.
- Acquire knowledge of new electronic defence techniques and technology trends

Course Contents

Unit I: Introduction to Electronic Warfare: Electronic defence, electronic combat (ESM-ECM-ECCM), SIGNIT, intercept system characteristics and functions, frequency coverage, analysis bandwidth, dynamic range, dynamic range requirements, sensitivity, noise figure, and Probability of intercept.

Unit II: Electronic Support Measures: Typical ESM systems, sensitivity, receivers - crystal video receiver, IFM receiver, superheterodyne receiver, channelized receiver, Bragg cell receiver, compressive receiver, digital receivers. DoA/AoA measurement emitter location - the role of emitter location, emitter location geometry, emitter location accuracy, amplitude-based emitter location, interferometer direction finding, interferometric DF implementation, direction finding using the Doppler principle, time of arrival emitter location.

Unit III: Electronic Countermeasures: Principles of electronic attack (EA), jamming-to-signal ratio, jamming types: burn-through, cover jamming, range deceptive jamming, inverse gain jamming, repeater jamming equations, noise jamming vs. deception, repeater vs. transponder, side lobe jamming vs. main lobe jamming, stand-off jamming, escort jamming, self-protection jamming. ECM techniques, on-board ECM systems, and off-board ECM systems

Unit IV: Electronic Counter-Countermeasures: Search radar counter-countermeasures, tracking radar counter-countermeasures.

Unit V: New Electronic Defence Techniques: New electronic defence techniques and technologies trend, shared apertures, anti-anti-radiation missile techniques, anti-stealth techniques, RF directed energy weapons, RWR, MAWS, Features and Capabilities of AEW&C and AWACS platforms, IFF Mark XII S
Course Outcomes
On completion of this course, the students will be able to: CO1: Acquire knowledge of Electronics warfare. CO2: To understand the support measure in EW. CO3: Gain knowledge of Electronics countermeasure. CO4: understanding of Electronics counter-countermeasure. CO5: understanding of advanced defence techniques.
Text Books/Reference Books
1. EW101: A First Course in Electronic Warfare, David Adamy, Artech House 2. EW102: A Second Course in Electronic Warfare, David Adamy, Artech House 3. Introduction to Electronic Defence Systems, Second Edition, Artech House by Filippo Neri 4. Introduction to Electronic Warfare, 1984, Schleher DC, Artech House 5. Microwave Receiver with EW applications, 1986, James Bao& Yen Tsui, Wiley and Sons 6. D. Curtis Schleher, Electronic Warfare in the Information Age, Artech House, Boston, London, 1999. 7. Skolnik, Radar hand book, Mc Graw Hill, 1972/1990. 8. Sergei A. Vakin, Fundamentals of Electronic Warfare, Artech House.

Course Code	Course Name	L – T – P	Credits
EE614	EMI/EMC Design	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Impart knowledge about EMI and EMC basics. • Introduce various near-field and far-field couplings. • Impart the EMI Reduction methods. • Provide practical applications of the EMI EMC topic			
Course Contents Unit I: Theory and principles of EMI/EMC: Sources of EMI, Conducted and Radiated EMI, Transient EMI, EMI/EMC definitions and units, Conducted, Radiated and Transient Coupling, Common Impedance Ground Coupling, Common Mode and Differential Mode			

coupling, Near-/Far-field coupling, Near Field Cable to Cable Coupling, Power Mains and Power Supply Coupling.

Unit II: EMI Tests and measurements, and control techniques: EMI Test Instrumentation/Systems, EMI Test, EMI Shielded Chambers, Open Area Test Site, TEM cell Antennas, Conducted Sensors/Injectors/Couplers, Military Test Method and Procedures (MIL-STD-461E), Calibration Procedures, Shielding, Filtering, Grounding, Bounding, Isolation Transformer.

Unit III: EMC Design of electronic systems: Requirements for Electronic Systems, System Design for EMC, PCB Traces Cross Talk, Impedance Control, Power Distribution Decoupling, Zoning, Transient Suppressors, Surge Protection Devices, Cable Routing, Signal Control, Component Selection and Mounting, Motherboard Designs, and Propagation Delay Performance Models.

Unit IV: EMI Standards and electromagnetic radiation hazards: Units of specifications, Civilian standards (CISPER, FCC, EN, IEC), Military standards -MIL-STD-461E, MIL-STD-1385, RADHAZ, HERO, NEMP, Biological Effects of EMR, Thermal and Non-Thermal, Prediction and Analysis of EMR Hazards, Mitigation Techniques.

Unit V: EMC Management concepts: Electromagnetic Environmental Effects (E3) Management, Spectrum Supportability Risk Assessment (SSRA), Spectrum Management and Requirements, Program management services to DoD and military departments, Military Department Operational Spectrum Management, EM Modeling and Simulation (M&S) services, steps for the proper development of an EMC control plan.

Course Outcomes

CO1: Learn the basics of EM interference and how it hampers the performance of other circuits, Basics of Electromagnetic Interference and Basics of EM Radiation, Components' behaviour at higher frequencies, Indian and International Standards of EMI/EMC.

CO2: Understand EMI Instruments and testing, shielded structures and their functioning, Techniques to detect the EMI disturbances and ways of calibration, Design of EMI-controlled circuitry.

CO3: Acquire knowledge of system-level analysis and design of EMI-controlled subsystems, Techniques to manage the ambient EMI, and related concepts.

CO4: Grasp knowledge of different testing levels of EMI, their classification, experimental validation of EMI concepts, interpretation, and inferences.

CO5: Gain working knowledge of EM modeling and simulation in an electromagnetic simulator, steps for designing and developing circuits and PCBs.

Text Books

1. Introduction to Electromagnetic Compatibility, 2nd Edition, Clayton R. Paul, ISBN: 978-0-471-75500-5, 1016 pages, December 2005, ©2006, Wiley publishers, Wiley Series in Microwave and Optical Engineering, 2006.

2. Principles of Electromagnetic Compatibility, B Keiser, Artech house, 2008.
3. V.P. Kodali, "Engineering Electromagnetic Compatibility", IEEE Publication, printed in India by S. Chand & Co. Ltd., New Delhi, 2000. Course Name: EMI/EMC DESIGN Course Code: EE614 2nd Ed. 333
4. Wilium DuffG., and Donald RJ, Series on "Electromagnetic Interference and Compatibility", Vol.5, EMI Prediction and Analysis Technique, 1972.
5. Weston David. A., "Electromagnetic Compatibility, Principles and Applications", 1991.
6. Kaiser BE., "Principles of Electromagnetic Compatibility", Artech House, 1987.
7. "Electromagnetic Interference and Compatibility IMPACT series", IIT Delhi,
8. Modules 1- 9. 7. C. R. Pal, "Introduction to Electromagnetic Compatibility", Ny, John Wiley, 1992.

Reference Books

1. Electromagnetic Compatibility Engineering, Henry W. Ott, ISBN: 978-0-470-18930-6, 872 pages, August 2009, Wiley Publishers.
2. Handbook for EMC- testing and measurement, Morgan D.
3. EMI & Compatibility Vol 1to 6 Electrical Noise & EMI SPEC, White, DON white
4. EMC for Product Designers, Tin Williams, Elsevier (2007).
5. Electromagnetic compatibility management guide for platforms, systems, and equipment, Standard Handbook, 1981 - Science - 125 pages, Pennsylvania State University.

Course Code	Course Name	L – T – P	Credits
EE615	GNSS RECEIVER DESIGN AND APPLICATIONS	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Impart knowledge about the GNSS Receiver
- Introduce GNSS Sensitivity & Applications.
- Impart the knowledge on application-based GNSS Receiver modification.
- Provide practical knowledge for advanced application of GNSS.

Course Contents

Unit I: Understanding applications as a function of GNSS receiver design: Detailed explanation of a Receiver Input Output Diagram, and explanation of possible applications at various sub-system levels.

Unit II: GNSS Receiver design and modifications for high sensitivity applications: Detailed elaboration of receiver design for high sensitivity applications and its nuances. Case study of an application Module.

Unit III: GNSS Receiver design and modifications for high signal dynamic applications: Detailed elaboration of receiver design for high signal applications and its nuances. Case study of an application.

Unit IV: GNSS Receiver design and modifications for high-integrity applications: Detailed elaboration of receiver design for aerospace applications and its nuances. Introduction to SBAS. Case study of an application, Module, need for integration with other sensors, and its merits, case study of one integration concept Module. Unit V: Introduction of GNSS in advanced system-level applications: Introduction and explanation of how GNSS is used in the determination of the attitude of a vehicle, precision farming, anti-collision techniques, say in a train, and a discussion on some new potential topics.			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Familiarize with applications as a function of GNSS receiver design CO2: Understand the basic concepts of GNSS receiver design and modifications for high-sensitivity applications, high signal dynamic applications CO3: Learn analysis of GNSS receiver design and modifications for integration with other sensors. CO4: Acquire knowledge of GNSS in advanced system-level applications. CO5: Apply knowledge of GNSS in precision farming, anti-collision techniques, etc.			
Text Books/Reference Books			
1. B. Hofmann Wollenhof, H. Lichtenegger, and J. Collins, “GPS Theory and Practice”, Springer Wien, new York, 2000. 2. Pratap Misra and Per Enge, “Global Positioning System Signals, Measurements, and Performance,” Ganga Jamuna Press, Massachusetts, 2001. 3. Ahmed El-Rabbany, “Introduction to GPS,” Artech House, Boston, 2002. 4. Bradford W. Parkinson and James J. Spilker, “Global Positioning System: Theory and Applications,” Volume II, American Institute of Aeronautics and Astronautics, Inc., Washington, 1996.			

Course Code	Course Name	L – T – P	Credits
EE 616	Multi-Sensor Integrated Navigation	3-0-0	3

Course Objectives: The primary objectives of this course are to: • Familiarize yourself with a navigation system and an introduction to the integrated navigation types of Navigation • Understand basic concepts of estimation theory • Acquire knowledge of Analysis of linear systems & Kalman filtering • Provide knowledge of integrated navigation • Deliver knowledge of Integration Schemes
Course Contents Unit I: Navigation system and introduction to integrated navigation: Inertial Navigation, Terrestrial navigation, Radio Navigation, Satellite Navigation – Properties of Inertial Navigation System, Need for Navigation aids - Navigation Aids: Doppler Velocity Sensor, Radar Altimeter, Distance Measuring Equipment, Comparison of Inertial navigation systems with satellite navigation systems, concepts of integrated navigation. Unit II & III: Basic concepts of estimation theory: Random signals, Random variables, Joint & conditional probability, Bayes Rule, continuous random variables, PDF, Gaussian Random variables, Correlation, covariance, independence, orthogonality, Transformation of random variables, General properties of random variables, Random process, stationary Process, Markov process, Ergodicity, Autocorrelation, Cross correlation, PSD, White noise & Colored noise, Decoloration, Random walk, and Wiener process problem of parameter estimation, Models for estimation of a parameter, Unbiased Estimators, Minimum Variance Unbiased Estimation - CRLB, Best Linear Unbiased Estimators(BLUE), MLE, LSE: Order-recursive Least squares, Sequential Least squares, Constrained Least Squares, Nonlinear Least Squares, Weighted LS, Recursive LS, Bayesian estimators: MMSE, MAP Unit IV: Linear systems & Kalman filtering: Introduction to linear systems, Dynamic systems representation using State space, State space Analysis, Concepts of observability, state observer - Discrete time State space models – State Models for stochastic process - Linear state estimation – Basics of Kalman Filter, Continuous Time Kalman Filter, Discrete Time Kalman Filter, Derivations of K.F. equations in discrete domain, K.F. Properties, K.F. implementation issues, K.F. implementation for asynchronous measurements, Computational aspects of K.F - Sequential KF, Information Filtering, Joseph stabilized form, Nonlinear applications: Linearization, LKF, EKF, UKF. Unit V: Integrated navigation: INS Mechanization equations, INS Error state dynamic equations, Pinson Error Model, Linearization, Augmented state equations with sensor errors, Navigation aiding measurements & Measurement Model, Observability analysis, GPS/INS integration, Integration by Complementary filtering, Integration using K.F., Kalman Filter Tuning, Integration Schemes: Uncoupled, Loosely coupled, Tightly coupled integration, Deep Integration/Ultra-tight Integration, Case studies: Barometer Aiding.
Course Outcomes After completing this course, the students will be able to: CO1: Familiarize with a navigation system and an introduction to the integrated navigation types of Navigation. CO2: Understand basic concepts of estimation theory CO3: Acquire knowledge of Analysis of linear systems & Kalman filtering CO4: Gain knowledge of integrated navigation CO5: Gain knowledge of Integration Schemes
Text Books/Reference Books 1. Fundamentals of Statistical Signal Processing: Estimation Theory by Steven M. Kay

2. Introduction to Random signals and Applied Kalman Filtering with Matlab exercises by Robert Grover Brown & Patrick Y. C. Hwang.
3. Optimal state estimation: Kalman, H_∞ , and NonLinear Approaches by Dan Simon.
4. Estimation with Applications to tracking and navigation by Yaakov Bar-Shalom, X. Rong Li, Thiagalingam, Kirubarajan.
5. Mathematical techniques in multi-sensor data fusion, David L. Hall, Artech House, Boston.
6. Applied Mathematics in Integrated Navigation Systems, Robert M Rogers
7. Kalman Filtering Theory & Practice using Matlab, Mohinder S. Grewal.
8. Aided Navigation GPS with High-rate sensors, Jay A Farrell

Course Code	Course Name	L – T – P	Credits
EE617	Inertial Navigation Systems	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Familiarize the basics of coordinate transformations: direction cosine matrix (DCM), Euler angles, quaternion; relation between DCM, Euler angles & quaternion.
- Know the concepts of strapdown inertial navigation and inertial measurements
- Grasp knowledge of the Inertial navigation system alignment
- Perform Navigation system simulation and error analysis

Course Contents

Unit I: Frames of references and inertial navigation fundamentals concept of frames of references: Inertial frames, non-inertial frames, geographic frame, geocentric frame, body frame; Principles of inertial navigation: types of inertial navigation, stabilized platform, and strap down systems, comparison; Earth models: ellipsoid geometry, ellipsoid gravity, earth gravity field, gravitational potential, gravity and gravitation, plum-bob gravity; Concepts of coordinate transformations: direction cosine matrix(DCM), Euler angles, quaternion; relation between DCM, Euler angles & quaternion.

Unit II: Concepts of strapdown inertial navigation inertial measurements: concept of specific force, basic principles of accelerometer: pendulous and vibrating beam, basic principle of gyroscope: mechanical and optical; Navigation equations formulation: forces in inertial & non-inertial frames, navigation equations in inertial & non-inertial frames, choice of reference frame, strap down system mechanization for different frames: inertial frames, earth-fixed frames, geographic frames.

Unit III: Strapdown inertial navigation computations sensor geometry: measurement model, concepts of DOP, failure detectability, optimal sensor geometry for different number of sensors; sensor modeling & compensation algorithms (scale factor, bias, misalignment, etc.), practical constraints; Failure detection and isolation: concepts of parity vectors, generalized likelihood test; Attitude propagation algorithm: using Euler angle, DCM, and quaternion; quaternion in terms of rotation vector, first and second order orientation vector algorithms for quaternion propagation, acceleration transformations, velocity & position update algorithms, numerical integration methods, comparison.

Unit IV: Inertial navigation system alignment: Initialization of inertial navigation system; Principle of alignment: alignment on a fixed platform: azimuth and level alignment, alignment on a moving platform: in-flight alignment and shipboard alignment: one-shot transfer alignment, measurement matching, methods of measurement matching; gyro-compassing; self-corrective alignment scheme. Unit V: Navigation system simulation and error analysis: development of perturbation models, attitude response under angular vibration, velocity response under combined angular and linear vibration, size effect errors, and modeling of sensor assembly response to system level vibration; specialized error analysis for strap down mechanization, INS Simulation: simulation of sensors, measurement electronics, and navigation algorithm; Navigation algorithm validation: comparison testing, closed loop simulations using NGC software together, hardware in-loop simulations; static navigation test, Monte Carlo & covariance analysis; General strap down algorithm validation: spin-cone, spin-accel, spin-rock-size.	
Course Outcomes	
On completion of this course, the students will be able to: CO1: Familiarize with frames of reference and inertial navigation fundamentals, the concept of frames of reference CO2: Understand strapdown inertial navigation computations, sensor geometry, and inertial navigation system alignment CO3: Analyze navigation system simulation and error analysis CO4: Acquire knowledge of advanced navigation concepts CO5: Understand the navigation algorithm and error analysis	
Text Books/Reference Books	
1. David A Vallado; Fundamentals of astrodynamics and applications, 2. Kenneth R Britting; Inertial navigation system analysis 3. David H Titterton& John L Weston; Strap down inertial navigation technology. 4. Robert M Rogers; Applied mathematics in integrated navigation systems 5. Paul G Savage; Strapdown analytics 6. Mark A Sturza; Navigation System integrity monitoring using redundant measurements, Navigation: journal of institute of navigation, vol35, No.4, winter1988-89, 7. Oleg Salychev; Applied Inertial Navigation: Problems & Solutions	

Course Code	Course Name	L – T – P	Credits
EE618	Indoor Navigation	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the basics of Navigation • Impart knowledge of positioning techniques • Know and apply knowledge to build models • Apply knowledge in localization and mapping			
Course Contents Unit I: Introduction: Location-Based Services (LBS), Indoor LBS and Ubiquitous Computing, Classical Research Areas Related to Indoor LBS, Classical Applications of LBS, Information Services, Navigation Service, Safety-of-Life Applications, Retail and Commerce, Management, Social Networking and Joint Activities, Gaming, A Short History of Navigation.			

Unit II: Basic positioning techniques: Methods for Location Determination, Method of Least Squares, Lateralization, Hyperbolic Lateralization, Angulation, Proximity Detection, Inertial Navigation, Fingerprinting, Properties and Evaluation of Positioning Systems, Examples of Positioning Systems, Pseudolites and High Sensitivity GNSS, Light-Based Systems, Camera-Based Systems, Radio-Based Systems, Inertial Navigation, Audio-Based Systems, Pressure-Based Systems. Unit III: Building-modeling: Coordinate Systems, Geometric Coordinate Systems, Symbolic Coordinate Systems, Location Models, Choice of Dimension, Vector Maps, Basic Algorithms for Vector Maps, Maps, Environmental Models, Set-Based Environmental Models, Graph-Based Environmental Models, Hybrid Approaches, Geometric Nearest Neighbors and Range Queries, Standardization, GML and City GML, Indoor OSM Unit IV: Position-refinement & trajectory-computing: Least Squares Estimation with Correlation, Recursive Least Squares Estimation, Discrete Kalman Filtering, The Extended Kalman Filter, Particle Filtering, Grid-Based Methods, Sampling Importance Resampling, The Process of Trajectory Computing, Trajectories, Trajectory Comparison, Hausdorff Distance, Fréchet Distance, Jaccard Distance, Closet Pair Distance, Euclidean Distance Sum, Dynamic Time Warping, Longest Common Subsequence (LCSS), Edit Distance on Real Sequences, Edit Distance with Real Penalties, Outlook, Trajectory Computing for Indoor LBS, Trajectory Computing for Positioning, Movement Patterns, Spatial Movement Patterns, Group-Based Motion Patterns. Unit V: Event-detection for indoor LBS & simultaneous localization and mapping in buildings: Event-Driven Applications, Event Sources for Indoor Navigation, Primary Events from Environmental Knowledge, Primary Events from Infrastructure, Primary Events from User Interface, Primary Events from Positioning, Primary Events from Activity Recognition, Secondary Events Relevant to the Navigational Task, Data Sources for SLAM, Data from Inertial Navigation Systems, Data from Laser Scanners, Data from Landmarks, Data from Camera Systems, Important Algorithms for SLAM Systems, Visual Feature Point Extraction, Optical Flow Estimation, Iterative Closest Points, Random Sample Consensus, Graph-Based Optimization Algorithms, Several Well-Known SLAM Approaches, Extended-Kalman-Filter SLAM, Fast SLAM, Grid-SLAM, Privacy and Security Considerations: Multiparty Computation, k-Anonymity, l-Diversity, Spatial and Temporal Cloaking, Differential Privacy, Private Information Retrieval, Quadratic Residues, Private Information Retrieval Using Quadratic Residuosity.
Course Outcomes On completion of this course, the students will be able to: CO1: Familiarize yourself with Location-Based Services (LBS), History of Navigation. CO2: Analyze Basic Positioning Techniques CO3: Build modeling maps, Indoor OSM, and position refinement. CO4: Apply the knowledge of Simultaneous Localization and Mapping in Buildings, Case Studies CO5: Acquire knowledge of event detection for indoor LBS
Text Books/Reference Books 1. Indoor Location-Based Services Prerequisites and Foundations, Werner, Martin, Publisher: Springer; 2014 Edition, ISBN-10: 3319106988. 2. Principles of GNSS, Inertial, and Multi-sensor Integrated Navigation Systems, Paul D. Groves Artech House, 2008 and 2013 Second Edition.

3. B. Hofmann Wollenhof, H. Lichtenegger, and J. Collins, "GPS Theory and Practice", Springer Wien, New York, 2000.
4. Pratap Misra and Per Enge, "Global Positioning System Signals, Measurements, and Performance," Ganga-Jamuna Press, Massachusetts, 2001.
5. Ahmed El-Rabbany, "Introduction to GPS," Artech House, Boston, 2002.
6. Bradford W. Parkinson and James J. Spilker, "Global Positioning System: Theory and Applications," Volume II, American Institute of Aeronautics and Astronautics, Inc., Washington, 1996.

Course Code	Course Name	L – T – P	Credits
EE619	Software Defined Radio	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamentals, architecture, and evolution of Software Defined Radio (SDR) systems. • Explore hardware and signal processing platforms used in SDR and their power-performance trade-offs. • Analyze various signal processing techniques and architectures for implementing SDR and cognitive radio systems. • Understand cognitive radio concepts, spectrum sensing techniques, and their real-world applications			
Course Contents Unit I: Introduction to SDR: What is Software-Defined Radio? The Requirement for Software-Defined Radio, Legacy Systems, The Benefits of Multi-standard Terminals, Economies of Scale, Global Roaming, Service Upgrading, Adaptive Modulation and Coding, Operational Requirements, Key Requirements, Reconfiguration Mechanisms, Handset Model, New Base-Station and Network, Architectures, Separation of Digital and RF, Tower Top Mounting, BTS Hoteling, Smart Antenna Systems, Smart Antenna System Architectures, Power Consumption Issues, Calibration Issues, Projects and Sources of Information on Software Defined Radio, Unit II: Basic architecture of a software defined radio: Software Defined Radio Architectures, Ideal Software Defined Radio Architecture, Required Hardware Specifications, Digital Aspects of a Software Defined Radio, Digital Hardware, Alternative Digital Processing Options for BTS Applications, Alternative Digital Processing Options for Handset Applications, Current Technology Limitations, A/D Signal-to Noise Ratio and Power 343 Consumption, Derivation of Minimum Power Consumption, Power Consumption Examples, ADC Performance Trends, Impact of Superconducting Technologies on Future SDR Systems. Unit III: Signal processing devices and architectures: General Purpose Processors, Digital Signal Processors, Field Programmable Gate Arrays, Specialized Processing Units, Tiler Tile Processor, Application-Specific Integrated Circuits, Hybrid Solutions, Choosing a DSP Solution. GPP-Based SDR, Non-real time Radios, High- Throughput GPP-Based SDR, FPGA-Based SDR, Separate Configurations, Multi- Waveform Configuration, Partial Reconfiguration, Host Interface, Memory-Mapped Interface to Hardware, Packet Interface, Architecture for FPGA-Based SDR, Configuration, Data Flow, Advanced Bus Architectures, Parallelizing for Higher Throughput, Hybrid and Multi-FPGA Architectures, Hardware Acceleration, Software Considerations, Multiple HA and Resource Sharing, Multi-Channel SDR, Airborne SDRs, Adhoc Network architecture for Airborne SDRs. Unit IV: Cognitive radio: techniques and signal processing: History and background, Communication policy and Spectrum Management, Cognitive radio cycle, Cognitive radio architecture, SDR architecture for cognitive radio, Spectrum sensing Single node sensing: energy			

detection, cyclostationary and wavelet-based sensing- problem formulation and performance analysis based on probability of detection vs SNR. Cooperative sensing: different fusion rules, wideband spectrum sensing- problem formulation and performance analysis based on probability of detection vs SNR. Unit V: Cognitive radio: Hardware and applications: Spectrum allocation models. Spectrum handoff, Cognitive radio performance analysis. Hardware platforms for Cognitive radio (USRP, WARP), details of USRP board, Applications of Cognitive radio.
Course Outcomes
On completion of this course, the students will be able to: CO1: Familiarize yourself with Software-Defined Radio and its various systems CO2: Analyze General-Purpose Processors and Digital Signal Processors CO3: Classify Cognitive radio architecture, SDR architecture, Applications of Cognitive radio, Spectrum sensing, Single node sensing with its hardware platforms. CO4: Apply the knowledge and skills to simulate SDR Flow in SystemVue, FPGA, and GNU Radio Simulation Software. CO5: Understand hardware and application of cognitive radio
Textbooks/Reference Books
“RF and Baseband Techniques for Software Defined Radio” Peter B. Kenington, ARTECH HOUSE, INC © 2005. 2. “Implementing Software Defined Radio”, Eugene Grayver, Springer, New York Heidelberg Dordrecht London, ISBN 978-1-4419-9332-8 (eBook) 2013. 3. “Cognitive Radio Technology”, by Bruce A. Fette, Elsevier, ISBN 10: 0-7506-7952-2, 2006.

Course Code	Course Name	L – T – P	Credits
EE620	SoC and Embedded Systems	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Know Embedded System Fundamentals • Understand Networking and Communication • Grasp knowledge of Advanced Embedded Technologies • Understand Real-Time Operating Systems (RTOS)			
Course Contents Unit I: Introduction: Definition and Classification, Overview of Processors and hardware units in an embedded system, Software embedded into the system, Embedded Systems on a Chip (SoC), and the use of VLSI designed circuits. Design flow of ASIC, SoC, and FPGA. Comparison of various processors such as generic microprocessor, microcontroller, DSP processors, and Tesla parallel computing hardware. Memory Interfacing and I/O Interfacing with processors. Unit II: Devices and buses for devices network: I/O Devices, Device I/O Types and Examples, Synchronous, I/o synchronous, and Asynchronous Communications from Serial Devices, Examples of Internal Serial-Communication Devices, UART, Parallel Port Devices, Sophisticated interfacing features in Devices/Ports, Timer and Counting Devices, I2C, USB, CAN, and advanced I/O Serial high speed buses, ISA, PCI,PCI-X, and advanced buses. Unit III: Embedded computing: Embedded processors, ARM processor, Architecture,			

Instructions and programming, Case Studies, Parallel Computing, CUDA platform for radar Application.	
Unit IV: Advanced embedded computing: Programmable System on Chip, Cypress PSoC Technology. Advanced DSP Processors. FPGA Technology towards Embedded system aspects- Pico blaze and micro blaze processors- Embedded RAM- Embedded multiplier FPGA coding using VHDL/ Verilog. Associated Labs: Assignments using Microcontroller kits, FPGA kits.	
Unit V: RTOS: Introduction to RTOS: Task Management, Memory management, Device Management, File management, Time management Scheduling Interrupt Handling, Event handling, inter process communication, Inter process synchronization, Networking Hardware: computer architecture, microprocessors, memories, peripheral devices, interconnections Case study: VxWorks and RTLinux RTOS in computing systems: embedded system, real time system, parallel system, and distributed system; CASE STUDY: underwater glider controller –Interfacing of various sensors such as inertial sensors and actuators using various processors and its performance comparison.	
Course outcomes:	
On completion of this course, the students will be able to:	
CO1: Learn the memory interface concept and the I/O interface concept in microprocessors and microcontrollers.	
CO2: Understand the various devices and buses, and network protocols in the various processors	
CO3: Understand the DSP Processor, PSoc, and CUDA platform for various applications.	
CO4: Acquire knowledge of the fundamentals of RTOS	
CO5: Gain knowledge of RTOS	
Text Books	
1. ARM System-on-Chip Architecture (2nd Edition) Steve Furber. 2. Real-time digital signal processing: Based on the TMS320C6000, Nasser Kehtarnavaz Advanced FPGA Design: Architecture, Implementation, and Optimization, Steve Kilts, IEEE press, Wiley, 2007.	
Reference Books	
1. http://www.xilinx.com/publications/xcellonline : Xcell Journal.	
2. Real-time digital signal processing: Based on the TMS320C6000, Nasser Kehtarnavaz.	
3. Advanced FPGA Design: Architecture, Implementation, and Optimization, Steve Kilts, IEEE press, Wiley, 2007.	

Course Code	Course Name	L – T – P	Credits
EE621	Digital Integrated Circuit Design	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the fundamentals of MOS design, including pseudo NMOS and CMOS inverter logic. • Learn how to design and analyze combinational and sequential MOS logic circuits. • Explore the principles of dynamic logic circuits. • Understand the operation and design of various semiconductor memories, including DRAM, SRAM, and flash memory.			

Course Contents	
Unit I: MOS Design: Pseudo NMOS Logic – Inverter, Inverter threshold voltage, output high voltage, output Low voltage, gain at gate threshold voltage, Transient response, Rise time, Fall time, Pseudo NMOS logic gates, Transistor equivalency, CMOS Inverter logic. Unit II: Combinational MOS logic circuits: MOS logic circuits with NMOS loads, Primitive CMOS logic gates – NOR & NAND gates, Complex Logic circuits design – Realizing Boolean expressions using NMOS gates and CMOS gates, AOI and OIA gates, CMOS full adder, CMOS transmission gates, Designing with Transmission gates. Unit III: Sequential MOS logic circuits: Behavior of bistable elements, SR Latch, Clocked latch and flip flop circuits, CMOS D latch and edge-triggered flip flop. Unit IV: Dynamic logic circuits: Basic principle, Voltage Bootstrapping, Synchronous dynamic pass transistor circuits, Dynamic CMOS transmission gate logic, High-performance Dynamic CMOS circuits. Unit V: Semiconductor memories: Types, RAM array organization, DRAM – Types, Operation, Leakage currents in DRAM cell and refresh operation, SRAM operation, Leakage currents in SRAM cells, Flash Memory, NOR flash and NAND flash. Emerging memory technologies: Phase Change Memory (PCM); Resistive Random-Access Memory, Magneto-resistive Random-Access Memory (MRAM); Ferroelectric Random-Access Memory (FeRAM); Comparison and future directions.	
Course Outcomes	
On completion of this course, the students will be able to: CO1: Acquire knowledge of the design of Combinational MOS Logic Circuits CO2: Learn sequential MOS Logic circuits CO3: Develop an understanding of large signal and small signal analysis of complex circuits CO4: Develop the knowledge of Semiconductor memories CO5: Apply the knowledge for the Simulation of circuits using PSpice and Microwind Backend Tools.	
Text Books	
1. Digital Integrated Circuit Design – Ken Martin, Oxford University Press, 2011 2. CMOS Digital Integrated Circuits Analysis and Design – Sung-Mo Kang, Yusuf Leblebici, TMH, 3rd Ed., 2011.	
Reference Books	
1. Introduction to VLSI Systems: A Logic, Circuit and System Perspective – Ming-BO Lin, CRC Press, 2011 2. Digital Integrated Circuits – A Design Perspective, Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, 2nd Ed., PHI	

Course Code	Course Name	L – T – P	Credits
EE622	RFIC Design	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the basic principles and challenges in RF circuit design, including non-linearity and noise. • Analyze and design key RF components like LNAs, mixers, oscillators, and synthesizers. • Evaluate the performance of RF circuits for gain, distortion, impedance matching, and noise. • Introduce system-level design concepts for RF transceivers, including transmitters, receivers,			

and synthesizers.

Course Contents

Unit I: Basic concepts in RF design: Time variance, Non-linearity, Effect of nonlinearity, Harmonic distortion, gain compression, Cross modulation, Intermodulation, Cascaded nonlinear stages, AM-PM conversion, Noise spectrum, effect of transfer function on noise, device noise, Sensitivity, Dynamic range.

Unit II: Components and devices: Integrated inductors, resistors, MOSFET and BJT AMPLIFIER DESIGN: Low Noise Amplifier Design – Wideband LNA - Design Narrowband LNA - Impedance Matching, Automatic-Gain-Control-Amplifiers.

Unit III: Mixers: Mixer - Qualitative Description of the Gilbert Mixer, Single balanced mixer, Double balanced mixer, Conversion Gain-Distortion Low Frequency Case: Analysis of Gilbert Mixer – Distortion - High-Frequency Case – Noise - A Complete Active Mixer. Switching Mixer - Distortion in Unbalanced Switching Mixer – Conversion Gain in Unbalanced Switching Mixer - Noise in Unbalanced Switching Mixer - A Practical Unbalanced Switching Mixer. Sampling Mixer - Conversion Gain in Single-Ended Sampling Mixer - Distortion in Single-Ended Sampling Mixer – Intrinsic Noise in Single-Ended Sampling Mixer - Extrinsic Noise in Single-Ended Sampling Mixer.

Unit IV: Frequency synthesizers: Phase Locked Loops - Voltage Controlled Oscillators – Phase Detector – Analog Phase Detectors – Digital Phase Detectors - Frequency Dividers - LC Oscillators – Ring Oscillators - Phase Noise - A Complete Synthesizer Design Example (DECT Application).

Unit V: Amplifiers and design concept: Power amplifiers, Adaptive Filters, Equalizers, Transceivers-system level considerations, Receiver design, Transmitter design, and Synthesizer design.

Course Outcomes

On completion of this course, the students will be able to:

CO1: Generalize the basic concept/idea of RF transceiver, its design issues, linearity, non-linearity, and distortion. Students will learn about device noise.

CO2: Learn the basics of a low-noise amplifier, oscillator, and mixer.

CO3: Learn the concept of Gilbert mixer, single balanced mixer, and double balanced mixer, amplifier, and some parts of the power amplifier are given to students.

CO4: Acquire knowledge of designing synthesizers

CO5: Apply knowledge and skills to design a power amplifier, its use in a transmitter, and a multi-tier transceiver architecture.

Textbooks/Reference Books

1. B. Razavi, "RF Microelectronics", Prentice-Hall, 1998
2. Bosco H Leung, "VLSI for Wireless Communication", Pearson Education, 2002.
3. Thomas H. Lee, "The Design of CMOS Radio –Frequency Integrated Circuits",
4. Cambridge University Press,
5. Emad N Farag and Mohamed I Elmasry, "Mixed Signal VLSI Wireless Design - Circuits
6. and Systems", Kluwer Academic Publishers, 2000.
7. Behzad Razavi, "Design of Analog CMOS Integrated Circuits" McGraw-Hill, 1999.
8. J. Crols and M. Steyaert, "CMOS Wireless Transceiver Design," Boston, Kluwer
9. Academic Pub., 1997.

Course Code	Course Name	L – T – P	Credits
EE623	Semiconductor Devices	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand fundamental semiconductor physics and carrier transport mechanisms. • Analyze the electrical behavior of key semiconductor devices like pn-junctions, MOSFETs, BJTs, and HBTs. • Explore device modeling, fabrication techniques, and high-frequency characteristics. • Introduce emerging transistor technologies and trends beyond traditional device scaling.			
Course Contents Unit I: Basic semiconductor physics: Crystal lattice, energy band model, density of states, distribution statistics – Maxwell-Boltzmann and Fermi-Dirac, doping, carrier transport mechanisms - drift, diffusion, thermionic emission, and tunneling; excess carriers, carrier lifetime, recombination mechanisms – SHR, Auger, radiative, and surface. Unit II: Junctions: p-n junctions – fabrication, basic operation – forward and reverse bias, DC model, charge control model, IV characteristic, steady state and transient conditions, capacitance model, reverse-bias breakdown, metal semiconductor junctions –fabrication, Schottky barriers, rectifying and ohmic contacts, I-V characteristics. Unit III: MOS Capacitors and MOSFETs: The MOS capacitor – fabrication, surface charge – accumulation, depletion, inversion, threshold voltage, CV characteristics – low and high frequency; the MOSFET – fabrication, operation, gradual channel approximation, simple charge control model (SCCM), I-V characteristic, second order effects – Velocity saturation, short-channel effects, charge sharing model, hot-carrier effects, gate tunneling, subthreshold operation – drain induced barrier lowering (DIBL) effect, unified charge control model (UCCM), MESFETs –fabrication, basic operation, I-V characteristics, high frequency response, back gating effect, HEMTs – fabrication, modulation (delta) doping, analysis of III-V heterojunctions, charge control, I-V characteristics, SPICE model. Unit IV: BJTs and HBTs: Fabrication, basic operation, minority carrier distributions and terminal currents, I-V characteristic, switching, second-order effects – base narrowing, avalanche multiplication, high injection, emitter crowding, Kirk effect, etc.; breakdown, high-frequency response, Gummel-Poon model, SPICE model; HBTs: - fabrication, basic operation, technological aspects, I-V characteristics, SPICE model. Unit V: Roadmap for next generation field effect transistors: Disadvantages associated with Scaling of FETs, Future roadmap for FETs, Recent trends in FETs: Fully Depleted SOI MOSFET, Fin-FET, Gate all around Fin-FETs, Thin sheet Fin-FET, Negative Capacitance FET (NCFET), Tunnel FET (TFET), Impact Ionization MOS (IMOS), and Future Improvement Possibilities.			
Course Outcomes On completion of this course, the students will be able to: CO1: Understand the fundamentals of Maxwell’s equations and Transmission line theory CO2: Acquire knowledge of the various Two-port Parameters: Z-Matrix, Y-Matrix, ABCD- Matrix, S-Matrix CO3: Understand the basics of microwave passive components: Directional Couplers, Filters, Power dividers CO4: Design and develop microwave active circuits such as amplifiers, Oscillators, multipliers, etc. CO5: Hands-on with Microwave measuring equipment and understanding the measurement of microwave circuits			
Textbooks/Reference Books			

1. Ben G. Streetman, Solid State Electronic Devices, Prentice Hall, 1997. 2. Richard S. Muller and Theodore I. Kamins, Device Electronics for Integrated Circuits, JohnWiley,1986.

Course Code	Course Name	L – T – P	Credits
EE624	Digital System Design Using FPGAs	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Impart knowledge about Digital System Techniques. - Introduce different VHDL-based designs - Impart the knowledge of Fault Modeling, Detection, and Test Pattern Generation Algorithms. - Provide practical knowledge of Digital Interfacing.			
Course Contents Unit I: Digital system design techniques: Combinational Circuit Design - Synchronous Sequential Circuit Design - Mealy and Moore model - State machine design - Analysis of Synchronous sequential circuit - State equivalence - State Assignment and Reduction – Analysis of Asynchronous Sequential Circuit - flow table reduction – races - state assignment - Design of Asynchronous Sequential Circuit - Designing with PLDs – Overview of PLDs – ROMs - EPROMs – PLA – PAL - Gate Arrays – CPLDs and FPGAs, Designing with ROMs - Programmable Logic Arrays - Programmable Array logic. Unit II: VHDL Basics and computation module designs: Introduction to VHDL - Behavioral modeling - Data flow modeling - Structural modeling - Basic language elements – Entity – Architecture - Configurations – Arrays declaration - Subprograms & operator overloading - Packages & libraries – Advanced Features - Model simulation - Realization of combinational and sequential circuits using VHDL – Registers – Flip flops - counters – Shift registers – Multiplexers - sequential machine – Multiplier – Divider, ALU, MAC, CORDIC, Introduction to Synthesis. Unit III: Fault modeling, detection and test pattern generation algorithms: Introduction to testing – Faults in Digital Circuits – Modeling of faults – Logical Fault Models – Fault detection – Fault Location – Fault dominance – Logic simulation – Test generation for combinational logic circuits – Testable combinational logic circuit design - Introduction to Design for Testability - BIST. Unit IV: Digital system design with real-time i/o interface: Sensors interface - uni-polar & bi-polar A/D converter - D/A converter interface - display devices interface - RS232, USB, Ethernet, VGA interface - RF data link - high voltage switch control - realy/AC/DC motor & buzzer control - PWM signal generation - PS/2 key-board & matrix keypad interface – digital camera interface, arbitrary data/signal generation – sensor data acquisition and writing/reading to/from .xlsx and .doc file - implementation of modulation schemes.			

Unit V: Contemporary designs and solutions: Design of data path components, Control path components - Design of a simple RISC CPU - Debugging using Embedded Logic Analyzers - Audio codec (AC97) interface – Test-bench design – Chip Scope Pro Analyzer - introduction to floating/fractional/fixed-point arithmetic operations - Xilinx Sys-Gen tools - MATLAB/VHDL interface with Sys-Gen tools -BERT interface – implementation of DPCM, data encryption/decryption system, EC techniques, communication modules design, DA based computations.
Course Outcomes
CO1: Familiarize with the design of Combinational and Synchronous, and Asynchronous Sequential Circuits. Gave an Overview of PLDs and PALs CO2: Cover the basic introduction of VHDL and the basic language elements. Various Combinational and Sequential circuits were designed using VHDL CO3: Gain an In-depth analysis of Faults and testability in digital systems, including modelling and detection CO4: Interface with various sensors and reading/writing to/from various file formats. Implementing various modulation schemes. CO5: Design a RISC CPU, data and control path components, and various floating/fractional/fixed-point arithmetic operations, and implement a Data encryption/Decryption system, Error correction, communication modules, BERT
Text Books
1.Parag K. Lala, "Digital System Design using programmable Logic Devices", Prentice Hall, NJ, 1994. 2. Geoff Bestock, "FPGAs and programmable LSI; A Designers Handbook", Butterworth Heinemann, 1996. 3. Miron Abramovici, Melvin A. Breuer and Arthur D. Friedman, “Digital Systems Testing and Testable Design”, John Wiley & Sons Inc. 4. Parag K. Lala “Fault Tolerant and Fault Testable Hardware Design” B S Publications, 2002. 5. J. Bhasker, "A VHDL Primer", Addison-Weseley Longman Singapore Pte Ltd. 1992.
Reference Books 1. Jesse H. Jenkins, "Designing with FPGAs and CPLDs", Prentice Hall, NJ,1994 2. Fundamentals of Logic Design – Charles H. Roth, 5th ed., Cengage Learning. 3. Kevin Skahill, "VHDL for Programmable Logic", Addison -Wesley, 1996 4. Z. Navabi, "VHDL Analysis and Modeling of Digital Systems", McGRAW-Hill, 1998 5. Digital Circuits and Logic Design – Samuel C. Lee, PHI 6. Smith, "Application Specific Integrated Circuits", Addison-Wesley, 1997 7. P.K. Lala, “Digital Circuit Testing and Testability”, Academic Press, 2002

Course Code	Course Name	L – T – P	Credits
EE625	High Performance DSP using FPGA	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Impart knowledge about High Performance DSP using FPGA.
- Introduce High-Performance Digital Computations
- Impart the knowledge of IP Core Design.
- Provide practical knowledge of System Implementation.

Course Contents

Unit I: Introduction to high performance digital computations: Digital system design, signal processing, fixed and floating point computations, standards for high resolution computing, Design with Vivado design suite (IP, SysGen for DSP and image processing, model composer, embedded development, AI and ML tools), testing with high speed logical analyzer, advanced features of modern FPGAs (Kintex-7, Virtex-7, Zynq-7000, Artix-7, Kintex Ultra Scale, Kintex Ultra Scale+, Virtex Ultra Scale, Virtex UltraScale+, ZynqUltraScale+ and RFSoc etc.), external memory interface, designs with advanced VHDL, advanced design with the PlanAhead analysis/design-tools, debugging techniques using the ChipScope Pro tools, FPGA power optimization.

Unit II: System implementation using hybrid simulink-programming tools: Introduction to SysGen tools, integration of MATLAB & Simulink with SysGen platform, Model composer algorithms, integrated mixed language-based design, high level synthesis, MATLAB & simulink, C and LabVIEW based HLS designs, massive parallel computations, designs with advanced XDC and STA, debugging techniques using Vivado logic Analyzer, designing with the Xilinx analog mixed signal solution.

Unit III: IP Core library and design managements: IP core design flow, IP core subsystems and integrations, parallelism, full/partial reconfiguration, flexible DSP blocks and multipliers, processor cores, embedded block RAM, embedded designs, standard communication interfaces, mixed signals based design, Multi-Rate Systems, MAC-Based FIR, Distributed Arithmetic and Multipliers Realization, FIFO, creating and managing reusable IPs, designs using Xilinx IP with Third-Party Synthesis Tools, Programming and Debugging Embedded Processors, SoC Processor Design, Embedded Micro Blaze Processor.

Unit IV: Algorithm implementations using DSP Tools: Ultra-fast algorithm design methodology, reconfigurable FPGA-based DSP Systems, real-time DSP System on Chip (SoC), Graphical Representation of DSP Algorithms, FIR/IIR filters, Adaptive filters, CORDIC algorithm implementations, multirate signal processing, FT/T_F analysis, spectral estimation and analysis, optimum and estimation techniques, image and speech processing, implementations of advanced transforms, Wavelet based designs.

Unit V: Contemporary applications and solutions: Video and image processing, database and data analysis, control systems, high-speed, wired, wireless communications, network accelerations, test and M/m systems, HT generations/ detections, AI and machine learning algorithm implementations, 5G adaptive beamforming, RF transceiver modules interface, software driven DDS/SDR platform interface, Gbps Ethernet/optical-fiber dynamic switching, Designing an Integrated PCI Express System, IoE designs, soft controller designs.			
Course Outcomes			
CO1: Understand system design basics and design tools like Vivado, ISE, etc. Also, learning about the features of different FPGA boards			
CO2: Learn different hybrid programming tools for system implementation, like integration of MATLAB & Simulink, C & LABVIEW, etc. Learning IP core design for various DSP applications			
CO3: Learn design algorithms for real-time DSP systems and different transforms. Also, learning the applications of FPGA in modern technologies			
CO4: Learn FPGA hardware and use it for real-time experiments			
CO5: Understand Beamforming, transceiver designs, and implementation of AI and ML			
Text Books/Reference Books			
1. Michael P, Digital Signal Processing 101: Everything You Need to Know to Get Started, 2010, Elsevier. 2. Steve K, Advanced FPGA Design: Architecture, Implementation, and Optimization, 2007, IEEE. 3. Sanjay Churiwala, designing with Xilinx® FPGAs: Using Vivado, 2017, Springer. 4. Roger Woods et al., FPGA-based Implementation of Signal Processing Systems, 2017, Wiley. 5. Donald G. Bailey, Design for Embedded Image Processing on FPGAs, 2011, IEEE. 6. Uwe Meyer-Baese Digital Signal Processing with Field Programmable Gate Arrays, 2013, Springer. 7. Nasser Kehtarnavaz, Digital Signal Processing Laboratory: LabVIEW-Based FPGA Implementation, 2010, Brown Walker press. 8. https://www.xilinx.com/support.html#knowledgebase .			

Course Code	Course Name	L – T – P	Credits
EE626	Compressed Sensing and Sparse Signal Processing	3-0-0	3

Course Objectives: The primary objectives of this course are to: • Introduce the fundamentals of compressive sensing (CS) and its connection to linear algebra and sparse signal representation. • Understand theoretical principles. • Explore measurement matrix design and properties for reliable sparse signal acquisition. • Learn and implement reconstruction algorithms, including convex optimization methods and greedy approaches. • Develop practical skills in CS through MATLAB-based implementation, simulation, and performance evaluation of algorithms			
Course Contents Unit I: Introduction: Introduction to CS, Review of Linear Algebra Unit II: Sparse Representations: Motivations and basic formulations, Uniqueness of sparse representation. Unit III: Measurement Matrices: Null Space Property, Restricted Isometry Property (RIP), Johnson Lindenstrauss Lemma, Random Matrices and RIP. Unit IV & V: Reconstruction Algorithms: Convex Optimisation methods, Basis Pursuit, Basis Pursuit Demonising, Introducing software packages like L1-magic, sparselab, etc. Greedy Algorithms: Matching Pursuit, Orthogonal Matching Pursuit, Subspace Pursuit, Compressive Sampling Matching Pursuit. Theoretical Guarantees of the algorithms, Implementation of the algorithms in Matlab, and simulations.			
Course Outcomes On completion of this course, the students will be able to: CO1: Generalize the concept of compressed sensing. CO2: Gain the theory of the null space property and RIP. CO3: Acquire the basics of convex optimization and basis pursuit CO4: Apply knowledge and skills to demonstrate in a short project			
Text Books/Reference Books 1. A Mathematical Introduction to Compressive Sensing, Simon Foucart, Holger Rauhut, Springer New York, 21-Jun-2013 2. Compressed Sensing: Theory and Applications, Yonina C. Elda, Cambridge University Press			

Course Code	Course Name	L – T – P	Credits
EE627	Signal Theory, Linear Algebra & Transform Techniques	3-0-0	3

Course Objectives: The primary objectives of this course are to: • Develop a solid foundation in probability theory and random processes for modeling and analyzing stochastic signals. • Apply transform techniques (Laplace, Z, Fourier, Wavelet) for signal analysis, system characterization, and efficient computation. • Understand and utilize properties of Gaussian processes, stationarity, and spectral analysis in signal processing contexts. • Strengthen knowledge of linear algebra concepts, including vector spaces, transformations, eigen analysis, and singular value decomposition. • Integrate probability, transforms, and linear algebra to solve practical problems in signal and system analysis.
Course Contents Unit I & II: Probability and Random variables: Random variables, Probability Distribution, and Density functions, Normal or Gaussian Random Variables, Multiple Random Variables, Correlation, Covariance and Orthogonality, Transformation of Random variables, Multivariate Normal Density Function, Linear Transformation and General Properties of Normal, Random Variables, Mathematical Description of Random Signals, Concept of a Random Process, Probabilistic Description of a Random Process, Gaussian Random Process, Stationarity, Ergodicity, and Classification of Processes, Autocorrelation Function, Cross-Correlation Function, Power Spectral Density Function, Cross Spectral Density Function, White Noise. Unit III: Transform Techniques: Laplace Transform: Introduction, Region of absolute convergence, Properties, Convolution, Inverse Laplace transform. Z TRANSFORM: Basic Properties, z-transform inversion, Difference equation. FOURIER TRANSFORM: Prelude to Fourier series, Transform properties, Discrete Fourier Transform, Properties, FFT, fast convolution. WAVELET TRANSFORM: Continuous wavelet transforms, Different wavelets, and multi-resolution analysis. Unit IV & V: Linear Algebra: General (real) vector spaces, Subspaces, Linear independence, Dimension, Norms, Orthogonal bases and Gram-Schmidt orthogonalization, Linear transformation, Kernel and range, Inverse transformations, Matrices of linear transformations, Change of basis, Similarity, Eigen values and Eigen vectors, Diagonalization, Orthogonal diagonalization of symmetric matrices, Singular value decomposition, and its applications.
Course Outcomes On completion of this course, the students will be able to: CO1: Learn the basics of random variables, probability, density functions, and correlation. CO2: Gain the theory of the Laplace transform and the Wavelet transform. CO3: Acquire the basics of orthogonal basis, linear independence ization convex optimization, and basis pursuit. CO4: Learn the application of SVD and EVD to demonstrate using a short project.
Text Books 1. Linear Algebra and its Applications, 1980, Gilber-strang, Academic press 2nd Edn, 2. Probability, Random Variables, and Stochastic Processes, 1965, Athanasios Papoulis, McGraw Hill.
Reference Books

1. Probability & Random Processes with Applications to Signal Processing, 2001, 3Edn. Henry Stark and John W Woods, Prentice Hall.
2. Introduction to linear algebra, 1984, Roger C. Meehan, Harcourt Brace Jovanovich Publishers.
3. First Course in Linear Algebra, 1983, P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Wiley Eastern.
4. Signal Processing, 1975, Mischa Schwartz and Leonard Shaw, New York, McGraw-Hill.

Course Code	Course Name	L – T – P	Credits
EE628	Advanced Electronics Systems	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the Analog IC Design Flow • Grasp knowledge about sensors • Design and realize Analog ICs • Design and realize Digital ICs			
Course Contents Unit I: Introduction: Analog IC Design Flow -Digital IC Design Flow- Bipolar and CMOS Technology. Unit II: Sensors: Sensors as system components- Temperature sensors- Force and pressure sensors- Magnetic field sensors – Optical sensors - Microwave sensors - Miscellaneous sensors –MEMS-Fabrication steps. Unit III: Analog IC Design: Analog Conditioning Circuits. Advanced Current Sources & sinks; Voltage Reference circuit, Operational amplifiers - Architectures-Instrumentation Amplifiers, feedback-Filter Design-ADC-DAC. Concepts of Virtual Instrumentation. Unit IV: Digital IC Design: MOS inverter- Static and switching characteristics, Combinational MOS logic circuits –static logic, Synchronous system, and Sequential circuits design. Unit V: RF Microelectronics: Low Noise Amplifier (LNA), Mixer, Oscillator, VCO and PLL, Power Amplifier-Transceiver Architecture.			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Learn the basics of Analog IC Design Flow, Digital IC Design Flow, Sensors, and advanced topics CO2: Gain the theory of Analog IC Design CO3: Acquire the basics of Digital IC Design CO4: Learn the basics and applications of RF Microelectronics			
Text Books/Reference Books			

1. Jan M. Rabaey; Anantha Chandrakasan; Borivoje Nikolić, "Digital Integrated Circuits A Design Perspective", (Second Edition) Prentice-Hall Electronics and VLSI Series. (2003)
2. Behzad Razavi, "Design of Analog CMOS integrated circuits", McGraw Hill International Edition. 2001.
3. Behzad Razavi, "RF Microelectronics", PHI International Second Edition. 2012.
4. Neil H.E. Weste, Kamran Eshraghian, "Principles of CMOS VLSI Design, Addison-Wesley Publishing Company.
5. Handbook of Modern Sensors by Fraden
6. D. V.S. Murthy, Transducers in instrumentation, Prentice Hall, 1995.
7. J. P. Bentley, Principles of measurement systems, Wiley, 1989
8. J. W. Gardner, Microsensors, principles and applications, Wiley, 1996.
9. S.M. Sze, Semiconductor Sensors, Wiley, 1994.

Course Code	Course Name	L – T – P	Credits
EE630	Sonar Signal Processing	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the basics of sound propagation and sonar evolution. • Understand underwater acoustic channel models. • Study ambient and radiated noise and their impact on sonar performance. • Analyze target reflection, scattering, and detection techniques. • Explore shallow water acoustics and passive sonar classification methods.			
Course Contents Unit I: Historical Background and Basics of Sound: History of sonar evolution, basics of sound measurement, measurement parameters, sound velocity profile and variation, and medium parameters. Unit II: Underwater Channel Models: Multipath Propagation, Ray Model, Helmholtz Equation, Wave Propagation, Adiabatic Model, PE model, Computational Ocean Acoustics. Unit III: Ambient Noise in the Ocean and Sonar Equation: Sources of sound in the ocean, propagation impact, characteristics of the sources, and their impact on sonar performance. Sonar parameters, sonar equation for active and passive sonar, Components of radiated noise, transmission of the components, propulsion types and their characteristics, ship design, and stealth aspects. Unit IV: Reflection and Scattering by Sonar Targets: Active sonar target characteristics, design and stealth aspects, Sensor performance and self-noise characteristics, ROC, statistical analysis for detection, State-of-the-art. Unit V: Shallow Water Acoustics and Passive Sonar: Deep Vs Shallow waters, Propagation in Tropical Littoral Waters, Band-limited Channel Characteristics, Fluctuations of a Shallow Water Underwater Channel, Feature Extraction, Feature Transformation, Acoustic Signature Characteristics, Classification Algorithms, Practical Classifiers, Cepstral Features			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Understand the basics of Sound and underwater channel models CO2: Understand the ambient Noise and radiated noise in the ocean CO3: Understand the reflection and scattering by sonar targets CO4: Acquire knowledge of shallow water acoustics and a passive Sonar classifier			

Text Books
1. Underwater Acoustic System Analysis, W S Burdic. 2. R. O. Nielsen, Sonar Signal Processing (Artech House, Boston, 1991).
Reference Books
1. Paul C. Etter, Underwater Acoustic Modelling and Simulation (Spon Press, Taylor and Francis Group, London and New York, third edition, 2003).

Course Code	Course Name	L – T – P	Credits
EE630	Sonar System Engineering	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Introduce the fundamentals of underwater sound and sonar equations.
- Understand sonar array structures and beamforming techniques.
- Study sound propagation in the ocean and related models.
- Analyze various noise sources in sonar systems.
- Characterize and compare passive and active sonar systems.

Course Contents

Unit I: Sound: Wave motion, Sound pressure, Reference intensity, Source level, Radiated power, Limitations to sonar power, Cavitation, Interaction, Octave Bands, dB Scale, Far Field and Near Field Measurements, Projector sensitivity, Hydrophone sensitivity, Spectrum level, Sound in air and sea water.

Unit II: Sonar Equations: The Active and Passive Sonar Equation. Sonar Parameters, Sound Velocity Profile (SVP), Sonar Performance, Limitations of the Sonar Equation, Detection Threshold, and Receiver Operating Curve (ROC).

Unit III: Arrays: Beam Forming, Beam Steering, Beam Patterns, Uniform Linear Arrays (ULA), Cylindrical Arrays, Shading, Delay and Sum Beam forming, Conformal Arrays, Three- dimensional Arrays, Cross Arrays, Spherical Arrays, Receiver and transmitter Arrays, Directivity Index, Sonar Domes, transducer design and characteristics,

Unit IV: Propagation of Sound: Propagation loss, spreading losses, Absorption losses, Propagation in the real ocean, speed of sound, Sound speed profiles, Deep sound channel, multi-path propagation, SOFAR Channel, Surface duct propagation, Convergence zone propagation, Bottom bounce propagation, Propagation loss models, Ray theory and the wave propagation models, Channel models.

Unit V: Noise in Sonar Systems: Sonar System Noise, Self-Noise, Ambient Noise in the Ocean, Flow Noise, Radiated Noise, Noise Factor of a Sonar, Figure of Merit, Practical Noise Levels, Radiated Noise, Ambient Noise Characteristics, LOFAR & DEMON, Passive Sonar Detection, Passive Sonar Classifier, Operational Limitation of Passive Sonars, Evolution of Passive Sonars, Acoustic Signatures, Ranging, Pulse Characteristics, CW Sonars, Reverberation Levels, Target Strengths, Echo Characteristics, Sediment Classification, Doppler.

Course Outcomes

On completion of this course, the students will be able to:

CO1: Understand the SONAR Equation and its fundamentals

CO2: Learn array concepts and Beam forming in SONAR applications

CO3: Learn about various Noises in SONAR

CO4: Characterize Passive and Active SONAR

Text Books
1. Sonar for Practicing Engineers, Third Edition by A. D. Waite; WILEY, 2002.
Reference Books
1. Principles of Underwater Sound, R J Urick, Third Edition, 1983.

Course Code	Course Name	L – T – P	Credits
EE631	Satellite Communication	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Understand the basics of satellite systems, orbits, and launching methods
- Grasp knowledge of the Geostationary orbit & Space segment
- Understand the phenomenon related to ground and space
- Impart knowledge in DBS

Course Contents

Unit I: Overview of satellite systems, orbits, and launching methods: Introduction, Frequency Allocations for Satellite Services, Kepler's First Law, Kepler's Second Law, Kepler's Third Law, Definitions of Terms for Earth-orbiting Satellites, Orbital Elements, Apogee and Perigee Heights, Orbital Perturbations, Effects of a Non-spherical Earth, Atmospheric Drag, Inclined Orbits, Sidereal Time, Equatorial Coordinate System, Predicting Satellite Position.

Unit II: Geostationary orbit & Space segment: Introduction, Antenna look angles, Limits of visibility, Near-geostationary orbits, Earth eclipse of satellite, Sun transit outage, Power supply, Attitude control, spinning satellite stabilization, Station keeping, Transponders, Antenna subsystem.

Unit III: Earth segment & Space link: Introduction, Receive-Only Home TV Systems, Outdoor Unit, Indoor Unit for Analog (FM) TV, Master Antenna TV System, Transmit-Receive Earth Stations, Various losses in the systems, System noise, Carrier-to-Noise ratio for uplink and downlink, Effects of rain, Rain-fade margin, Downlink rain-fade margin, Intermodulation noise

Unit IV: Satellite access: Preassigned FDMA, Demand-Assigned FDMA, FDMA downlink analysis, Comparison of uplink power requirements for FDMA & TDMA. On-board signal processing for TDMA/FDMA operation, Satellite switched TDMA, CDMA

Unit V: Direct broadcast satellite services: Introduction, Orbital Spacings, Power Rating and Number of Transponders, Frequencies and Polarization, Transponder Capacity, Bit Rates for Digital Television, MPEG Compression Standards, Forward Error Correction, Home Receiver Outdoor Unit (ODU), Home Receiver Indoor Unit (IDU), Downlink Analysis, Uplink, Problems, Satellite Mobile Services, VSATs, Radarsat, Global Positioning Satellite System.

Course Outcomes

On completion of this course, the students will be able to:

CO1: Understand the basics of Satellite Systems, learning about orbital systems and sub-systems

CO2: Learn Earth-to-Satellite linking and its calculations for losses

CO3: Understand the Earth segment and its link to space CO4: Know about applications of direct satellite broadcasting, like GPS and other mobile services CO5: Understand the Uplink & Downlink Analysis, Satellite Mobile Services, VSATs, GPS, etc.
Text Books/Reference Books
1. Satellite Communications, Dennis Roddy, McGraw-Hill Publication Third edition 2001. 2. Satellite Communications – Timothy Pratt, Charles Bostian and Jeremy Allnutt, WSE, Wiley Publications, 2nd Edition, 2003. 3. Satellite Communications Engineering – Wilbur L. Pritchard, Robert A Nelson and Henri G.Suyderhoud, 2nd Edition, Pearson Publications, 2003. 4. Timothy Pratt – Charles Bostian& Jeremy Allmuti, Satellite Communications, John Willy & Sons (Asia) Pvt. Ltd. 2004. 5. Wilbur L. Pritchards Henri G.SuyderHond Robert A. Nelson, Satellite Communication Systems Engineering, Pearson Education Ltd., Second edition 2003. 6. Satellite Communications: Design Principles – M. Richharia, BS Publications, 2nd Edition, 2003.

Course Code	Course Name	L – T – P	Credits
EE632	Advanced Communication Systems	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the basic terms such as sampling, quantization, and various transforms • Know about baseband and passband transmission • Apply modulation and demodulation techniques for signals • Know about information theory and channel capacity			
Course Contents Unit 1: Introduction: Block diagram of digital communication system, Review of Fourier Transform properties, Discrete Sequences, DTFT, Z-Transform, Channel capacity, Shannon's limit, sampling Theorem -Mathematical proof of sampling and reconstruction – ideal and Flat top sampling, Band pass sampling. Digital Representation of Analog Signals, Pulse code modulation, generation and detection of PCM, Uniform quantization and companding, Differential PCM; Delta modulation, Adaptive delta modulation; Signal-to-Noise Ratio calculations in PCM, DM. Unit II: Base band data transmission: Communication over Band-limited AWGN Channel, ISI in band-limited channels, Zero-ISI condition- the Nyquist criterion, Solution for zero ISI, Raised cosine filters, Partial response signalling-Duo binary encoding, M-ary baseband system, eye pattern, adaptive Equalization. Unit III: Modulation techniques: Binary Baseband Digital Modulation Techniques, digital modulation techniques: ASK, BPSK, BFSK, DPSK, QPSK, and M-ary signaling; M-ary Baseband Digital Modulation Techniques, PSK & QPSK, Offset QPSK, Minimum Shift Keying (MSK), Passband Waveforms for M-ary signaling, Passband Modulations for Band Limited Channels, Baseband & Passband Digital Unit IV: Demodulation techniques: General Issues & Concepts, Matched Filters, Coherent Demodulation, Coherent Demodulation for Binary Wave Form, Coherent & Noncoherent Receivers for Orthogonal Signaling (OOK & FSK), Signal & Noise Statistics in Coherent			

&Noncoherent Receivers, Error Rates for Binary Signaling: Coherent Receivers, Performance of Non-Coherent FSK & Differential Phase Shift Keying, Demodulation of DPSK & M-ary Signals, Performance of M-ary Digital Modulations. Unit V: Performance analysis information theory: Entropy, Joint Entropy and Conditional Entropy, Relative Entropy and Mutual Information, Chain Rules, Data-Processing Inequality, Fano's Inequality. Source Coding and Data Compression: Kraft Inequality, Huffman Codes, Optimality of Huffman Codes, Linear Binary Block Codes: Introduction, Generator and Parity-Check Matrices, Repetition and Single-Parity-Check Codes, Binary Hamming Codes, Error Detection with Linear Block Codes, Weight Distribution and Minimum Hamming Distance of a Linear Block Code, Hard-decision and Soft-decision Decoding of Linear Block Codes, Cyclic Codes, Parameters of BCH and RS Codes, Interleaved and Concatenated Codes, Convolutional Codes: Encoder Realizations and Classifications, Minimal Encoders, Trellis representation, MLSD and the Viterbi Algorithm, Bit-wise MAP Decoding and the BCJR Algorithm.	
Course Outcomes	
On completion of this course, the students will be able to: CO1: Review the Fourier Transform, DTFT, Z-Transform, sampling theorem, PCM, DM, etc. CO2: Understand the communication over the AWGN channel, coding, and equalization techniques CO3: Acquire knowledge of digital modulation and demodulation techniques CO4: Acquire knowledge of Signal & Noise Statistics in Coherent &Noncoherent Receivers CO5: Develop a basic understanding of source coding and entropies	
Text Books/Reference Books	
1. Sam Shanmugam, "Digital and analog communication system", John Wiley,2005. 2. Herbert Taud, Donald L. Schiling, GoutamSaha, "Principles of Communication Systems", – 3rdEdition, McGraw-Hill, 2008. 3. Elements of Information Theory by Thomas Cover, Joy Thomas 4. Channel Codes: Classical and Modern by William Ryan, Shu Lin 5. Digital Communications –Simon Haykin, Jon Wiley,2005 2. Wayne Tomasi, "Electronic communications systems"-5 th edition, Pearson publication 6. Information Theory and Reliable Communication by Robert Gallager.	

Course Code	Course Name	L – T – P	Credits
EE633	Underwater Communications	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the fundamentals of underwater acoustic communication systems. • Explore the physical characteristics of underwater channels and their impact on signal transmission. • Study modulation, coding, and signal processing techniques suitable for underwater environments. • Analyze challenges such as noise, multipath, and Doppler effects in underwater communication. • Learn about current technologies and applications in underwater communication networks.			

Course Contents			
Unit I: Introduction: Background and Context- Early Exploration of Underwater Acoustics- Underwater Communication Media, Underwater Systems and Networks,			
Unit II: UWA Channel: UWA Channel Characteristics, Sound Velocity, Propagation Loss- Time-Varying Multipath-Acoustic Propagation Models-Ambient Noise and External Interference, Passband Channel Input– Output Relationship, Linear Time-Varying Channel with Path-Specific Doppler Scales, Linear Time-Varying Channels with One Common Doppler Scale, Linear Time-Invariant Channel-Linear Time-Varying Channel with Both Amplitude and Delay Variations-Linear Time-Varying Channel with Frequency Dependent Attenuation.			
Unit III: UWA Modulation techniques: Modulation Techniques for UWA Communications, Frequency Hopped FSK, Direct Sequence Spread Spectrum, Single Carrier Modulation, Sweep-Spread Carrier (S2C) Modulation, Multicarrier Modulation.			
Unit IV: MIMO-UWA: Multi-Input Multi-Output Techniques- Recent Developments on Underwater Acoustic Communications.			
Unit V: OFDM Basics: Zero-Padded OFDM, Cyclic-Prefixed OFDM -OFDM Related Issues-ZP-OFDM versus CP-OFDM -Peak-to-Average-Power Ratio -Power Spectrum and Bandwidth -Subcarrier Assignment- Overall Data Rate -Design Guidelines -Implementation via Discrete Fourier Transform -Challenges and Remedies for OFDM -Benefits of Diversity Combining and Channel Coding -MIMO OFDM.			
Course Outcomes			
On completion of this course, the students will be able to:			
CO1: Learn the basics of Underwater Acoustics-Underwater Communication Media, Underwater Systems and Networks			
CO2: Gain the theoretical knowledge of UWA Channel Characteristics, Sound Velocity, and Doppler scale			
CO3: Acquire the basics of Modulation Techniques for UWA Communications			
CO4: Learn the application of Multi-Input Multi-Output Techniques for underwater Acoustic Communications			
Text Books/Reference Books			
1. Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung G. Kang, “MIMO-OFDM Wireless Communications with MATLAB”, John Wiley & Sons Ltd, 2010.			
2. Shengli Zhou, Zhaohui Wang, “OFDM for Underwater Acoustic Communications”, John Wiley & Sons Ltd, 2014.			

Course Code	Course Name	L – T – P	Credits
EE 634	Monolithic Microwave Integrated Circuit	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Develop an understanding of planar technologies such as strip lines, microstrip lines, etc. • Provide knowledge of microwave passive components such as branch line couplers, power dividers, circulators, phase shifters, etc. • Equip students with knowledge of microwave active circuits, stability, and gain analysis through the Smith chart. • Introduce CAD techniques for oscillator, mixer designs • Foster the ability to critically evaluate and optimize MMIC, hybrid MIC			

Course Contents Unit I: Introduction to microwave integrated circuits and applications: Introduction, Micro strip Lines, Characteristic Impedance of Micro strip Lines, Losses in Micro strip Lines, Quality Factor Q of Micro strip Lines, Parallel Strip Lines, Distributed Lines, Characteristic Impedance, Attenuation Losses, Coplanar Strip Lines, CPW lines, Shielded Strip Lines. methods of analysis in MIC: Analysis of MIC by conformal transformation, Numerical method, Hybrid Mode analysis, Losses in microstrip, Introduction to slot line, and coplanar waveguide. Unit II: Couplers and lumped elements: passive devices: Introduction to coupled micro strip, Even and odd mode analysis, coplanar circuits, Design and fabrication of microstrip components: Branch line couplers, Filters, switches, attenuators, Directional couplers, lumped elements for 169 MICs: Inductors, capacitors, resistors, multilayer techniques, Ferromagnetic substrates and inserts, microstrip circulators, Phase shifters, micro-machined passive components, Comparison with distributed circuits. Unit III: Microwave active devices: Microwave transistors, parametric diodes and amplifiers, PIN diodes, transferred electron devices, Avalanche diodes, IMPATT, BARITT devices. RF CMOS devices, Microwave BJTs, GaAs FETs, MSFETs, low noise and power GaAs FETs, and their applications, Design principles, active device CAD techniques for large signal oscillators design, Phase noise, MMIC_VCO, mixers. Unit IV: High & low power circuits: Introduction, Impedance transformers, Filters, High power circuits, Low power circuits, MICs in Radar and satellite; Amplifiers: Stability & gain analysis, matching techniques, reactively matched amplifier design, LNA Unit V: Fabrication methods: Fabrication process of MMIC, Hybrid MICs, Dielectric substances, thick film and thin film technology and materials, testing methods, Encapsulation, and mounting of devices.
Course Outcomes
After completing this course, the students will be able to: CO1: Develop an understanding of planar technologies such as strip lines, microstrip lines, etc. CO2: Acquire knowledge of microwave passive components such as branch line couplers, power dividers, circulators, phase shifters, etc. CO3: Understand microwave active circuits, stability, and gain analysis through the Smith chart CO4: Understand CAD techniques for oscillator, mixer designs CO5: Acquire knowledge of MMIC, hybrid MIC
Text Books/Reference Books
1. Gupta K.C and Amarjit Singh, “Microwave Integrated Circuits”, John Wiley, New York, 1975. 2. Hoffman R.K “Hand Book of Microwave Integrated Circuits”, Artech House, Boston, 1987. 3. Ravender Goyal, “Monolithic MIC; Technology & Design”, Artech House, 1989. 4. Ulrich L. Rohde and David P.N., “RF / Microwave Circuit Design for Wireless Applications”, John Wiley, 2000. 5. C. Gentili, “Microwave Amplifiers and Oscillators”, North Oxford Academic, 1986. 6. Annapurna Das and Sisir K Das, “Microwave Engineering”, Tata McGraw-Hill Pub. Co. Ltd., 2004. 7. Samuel. Y. Liao, “Microwave Circuit Analysis and Amplifier Design”, Prentice Hall. Inc., 1987. 8. Mathew N.O. Sadiku, “Numerical techniques in Electromagnetic”, CRC Press, 2001.

Course Code	Course Name	L – T – P	Credits
EE635	Inertial Sensors and Systems	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Understand the Basic principles of navigation and inertial navigation
- Impart knowledge of the Gyroscope and its working principle
- Know about Pendulous servo accelerometers
- Apply knowledge in designing and realizing Inertial navigation systems

Course Contents

Unit I: Basic principles of navigation and inertial navigation: Gimbaled platform and Strap down Navigation systems, Overview of Inertial Sensors.

Unit II: Gyroscope working principle: Single degree of freedom rate gyro and rate integrating gyro. Dynamically Tuned Gyroscope: Principle of operation, Design features, Single gimbal and dual gimbal flexures, Rebalance loop configuration, DTG errors and error model. Ring Laser Gyro: Principle of operation and different types, Sagnac Effect, Design features, Lock-in and Dither, RLG errors and error model.

Fiber Optic Gyro: Principle of operation, Difference with RLG, Design features, open loop and closed loop operation, Error sources in FOG, difference between Fiber optic laser gyro and ring laser gyro. Hemispherical Resonator Gyro: Principle of operation, Design features, HRG errors, and error model. Other types of gyros: Nuclear Magnetic Resonance Gyro, Electrostatically Suspended Gyro, Atom Interferometric Gyro, etc.

Unit III: Pendulous servo accelerometers: Configuration, working principle, and design of pendulous servo accelerometers. Servo accelerometer errors and error model. Other types of accelerometers: Vibrating Beam Accelerometer, Fiber optic Accelerometers, Atom Interferometric Accelerometer, etc.

Unit IV: MEMS Inertial sensors: Introduction to MEMS Inertial Sensors, Overview of MEMS Fabrication Techniques, MEMS Accelerometers: Pendulous and non-pendulous accelerometers, Resonant beam accelerometer, MEMS Gyros: Coriolis Vibrating gyro principle, Tuning fork gyro, Comb structure and Ring structure mechanizations.

Unit V: Inertial navigation systems: Gimbaled platform technology and Strap down system technology, their mechanization. Redundant Inertial Navigation Systems: Basic concepts of sensor redundancy, redundant sensor configurations, Sensor Failure detection and Isolation. Strap down INS realization: Basic concepts of system configuration, vibration isolation, and temperature control/compensation. Testing of Inertial Sensors and Systems: Basic concepts and test philosophy. Gyroscope Testing: Multi-position test and Rate test, Frequency response test, Thermal test, Magnetic sensitivity test, Vibration test, and Shock test. Accelerometer Testing: Multi-position test, Centrifuge test, Frequency response test, Thermal test, Magnetic sensitivity test, Vibration test, and Shock test. Gyro and Accelerometer error modeling and compensation. INS Testing: Rate test and multi-position test, Attitude test, Static navigation test, Hardware in Loop tests, Environmental tests like EMI, Thermal, Vibration, and Shock.

Course Outcomes

On completion of this course, the students will be able to:

CO1: Understanding the fundamentals of Navigation and Inertial Navigation, the gyroscope working principle, and different types of gyroscopes

CO2: Acquire knowledge of the configuration, working principle, design of servo accelerometers, and their types

CO3: Know the basics of MEMS Inertial Sensors, and Testing of Inertial Sensors and Systems

CO4: Understand Inertial Navigation Systems, Gimbaled platform technology, Strap down INS realization, etc.

Text Books/Reference Books
1. Gupta K. C. and Amarjit Singh, "Microwave Integrated Circuits", John Wiley, New York, 1975. 2. Hoffman R. K. "Hand Book of Microwave Integrated Circuits", Artech House, Boston, 1987. 3. Ravender Goyal, "Monolithic MIC; Technology & Design", Artech House, 1989. 4. Ulrich L. Rohde and David P.N., "RF / Microwave Circuit Design for Wireless Applications", John Wiley, 2000. 5. C. Gentili, "Microwave Amplifiers and Oscillators", North Oxford Academic, 1986. 6. Annapurna Das and Sisir K Das, "Microwave Engineering", Tata McGraw-Hill Pub. Co. Ltd., 2004. 7. Samuel. Y. Liao, "Microwave Circuit Analysis and Amplifier Design", Prentice Hall. Inc., 1987. 8. Mathew N.O. Sadiku, "Numerical techniques in Electromagnetic", CRC Press, 2001.

Course Code	Course Name	L – T – P	Credits
EE636	Navigation & Avionic Systems	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Understand the navigational methods
- Provide knowledge of avionics and its need.
- Deliver knowledge of Radio and satellite navigation
- Provide knowledge of radar reflectors and beacons

Course Contents

Unit I: Introduction: Various navigation methods, Dead Reckoning position (DR), estimated position (EP) & Observed Position, Gyroscopes, Mechanical, electromechanical, Ring Laser gyro, Fiber-optic gyro, Accelerometers

Unit II: Inertial navigation system: INS components: transfer function and errors- The earth in inertial space, the Coriolis effect- Mechanization. Platform and Strap down, INS system block diagram, Different coordinate systems, Schuler loop, compensation errors, Gimbal lock, Alignment

Unit III: Avionics: Need for Avionics in civil and military aircraft and space systems, Integrated Avionics and Weapon system, typical avionics sub-systems, Design and Technologies, VHF avionics Communication system, data link, Telemetry

Unit IV: Radio navigation: Different types of radio navigation, ADF, VOR/DME, Doppler, LORAN, DECCA and Omega, TACAN, ILS, MLS, GLS - Ground controlled approach system surveillance systems-radio altimeter

Unit V: Satellite navigation and hybrid navigation: Introduction to GPS description, basic principles, position and velocity determination, signal structure, DGPS, Introduction to Kalman filtering, Estimation and mixed mode navigation, Integration of GPS and INS, utilization of navigation systems in aircraft, Navigation and traffic control using ground based radar and airborne radar, Tactical Air Navigation (TACAN), TACAN Equipment, Fischer Plotting, Radar Navigation Aid: radar reflectors, radar beacons, Principle of superposition Navigation, Chart matching equipment, accuracy obtained by chart matching, PPI Simulations.

Course Outcomes

On completion of this course, the students will be able to: CO1: Learn the basics of navigation methods, DR position, and EP CO2: Gain the theory of INS components CO3: Acquire the basics of different types of radio navigation, LORAN, and DECCA CO4: Learn the GPS, position, and velocity determination
Text Books/Reference Books
1. Myron Kyton, WalfredFried,” Avionics Navigation Systems” John wiley& Sons, 2nd edition, 1997 2. Nagaraja, N.S. “Elements of Electronic Navigation”, Tata McGraw-Hill Pub. Co., New Delhi, 2nd edition, 1975. 3. Sen, A.K. & Bhattacharya, A.B. “Radar System and Radar Aids to Navigation”, Khanna Publishers, 1988 4. Data & Network Communication, Michael A. Miller – DELMAR (Thomson learning) / Vikas Publication.

Course Code	Course Name	L – T – P	Credits
EE637	ASIC Verification using System Verilog	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the fundamentals of ASIC design and verification flow. • Learn System Verilog language constructs for functional verification. • Develop testbenches using System Verilog features like classes, constraints, and randomization. • Apply assertions and functional coverage for effective verification. • Gain hands-on experience with simulation tools and debugging techniques.			
Course Contents Unit I: Introduction to functional verification languages, Introduction to System Verilog, System Verilog data types. System Verilog procedures, Interfaces, and modports, SystemVerilog routines. Unit II: Introduction to object-oriented programming, Classes and Objects, Inheritance, Composition, Inheritance v/s composition, Virtual methods. Parameterized classes, Virtual interface, Using OOP for verification, System Verilog Verification Constructs Unit III: System Verilog assertions: Introduction to assertion, Overview of properties and assertion, Basics of properties and sequences, Advanced properties and sequences, Assertions in design and formal verification, some guidelines for assertion writing. Unit IV: Coverage-driven verification and functional coverage in SV: Coverage Driven Verification, Coverage Metrics, Code Coverage, Introduction to functional coverage, Functional coverage constructs, Assertion Coverage, Coverage measurement, Coverage Analysis. SV and C interfacing: Direct Programming Interface (DPI) Unit V: Case studies: System Verilog-based Verification of UART, 8-bit ALU, RISC CPU.			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Understand the basics of System Verilog- data types CO2: Understand the programming concept of System Verilog CO3: Acquire knowledge of the verification tool by assertion coverage CO4: Analyze the case studies of module verification by System Verilog			

Text Books
1. “SystemVerilog for Design”: A Guide to Using SystemVerilog for Hardware Design and Modeling Sutherland, Stuart, Davidmann, Simon, Flake, Peter 2nd ed., 2006 2. “SystemVerilog for Verification”: A Guide to Learning the Testbench Language Features, Chris Spear, 2006 3. “Hardware Verification with System Verilog”: An Object-Oriented Framework Mintz, Mike, Ekendahl, Robert, 2007.
Reference Books
1. “A Practical Guide for System Verilog Assertions” Meyyappan Ramanathan

Course Code	Course Name	L – T – P	Credits
EE638	Mixed Signal IC Design	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand the fundamentals of analog, digital, and mixed-signal circuits. - Learn design methodologies and key building blocks like ADCs, DACs, and PLLs. - Develop skills in mixed-signal IC simulation, layout, and verification. - Address challenges like noise, power management, and analog-digital isolation. - Apply concepts to real-world applications through projects and case studies.			
Course Contents Unit I: Introduction and basic MOS Devices: Challenges in analog design- Mixed signal layout issues- MOS FET structures and characteristics, signal model– small signal model- single stage Amplifier- Source follower- Common gate stage – Cascode Stage. Unit II: Submicron circuit design: Submicron CMOS process flow, Capacitors and resistors, Current mirrors, Digital Circuit Design, Delay Elements – Adders-OP Amp parameters and Design. Unit III: Data converters: Characteristics of Sample and Hold -Digital to Analog Converters-architecture-Differential Non-Linearity-Integral Non-Linearity-Voltage Scaling- Cyclic DAC- Pipeline DAC-Analog to Digital Converters-architecture –Flash ADC Pipeline ADC-Differential Non-Linearity-Integral Non-Linearity Unit IV: SNR in Data Converters: Overview of SNR of Data Converters-Clock Jitters-Improving Using Averaging –Decimating Filters for ADC-Band pass and High Pass Sinc Filters-Interpolating Filters for DAC. Unit V: Switched capacitor circuits: Resistors, First-order low-pass Circuit, switched capacitor Amplifier, Switched Capacitor Integrator			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Develop the knowledge of Device modeling of MOSFET CO2: Illustrate the concept of small signal analysis of single and multi-stage amplifiers CO3: Learn designing switched capacitor circuits CO4: Demonstrate the Data converters and their applications CO5: Simulate circuits using PSpice and Microwind Backend Tools.			
Text Books/Reference Books			

1. Vineetha P. Gejji Analog and Mixed Mode Design, Prentice Hall, 1st Edition, 2011
- Jeya Gowri Analog and Mixed Mode Design Sapna publishing House 2011.
2. Gray Paul R, Meyer, Robert G, Analysis and Design of Analog Integrated Circuits, 3rd edition, John Wiley & Sons.
3. Jacob Baker, "CMOS Mixed-Signal circuit design", A John Willy & Sons, inc., publication, 2003.

Course Code	Course Name	L – T – P	Credits
EE639	Computer-Aided Design of VLSI Circuits	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamentals of CAD tools used in front-end and back-end VLSI design. • Develop proficiency in HDL-based modelling, simulation, and synthesis using industry tools. • Understand layout algorithms, testing methodologies, and post-layout processes. • Explore automated design flows including logic synthesis, physical verification, and test generation.			
Course Contents Unit I: Various CAD Tools for front-end and Back-end design, Schematic editors, Layout editors, and Place and Route tools. Introduction to VLSI Methodologies - VLSI Physical Design Automation - Design and Fabrication of VLSI Devices - Fabrication process. Unit II: Introduction to Design Tools: Introduction & Familiarity with Design Tools from various vendors e.g., Synopsis, CADENCE, Mentor Tools, etc. Verilog Basics - Modeling Levels - Data Types - Modules and Ports - Instances - Basic Language Concepts - Dataflow modeling - Behavioral Modeling and Simulation of systems/subsystems using Verilog HDL. Typical case studies. Unit III: Layout Algorithms Circuit partitioning, placement, and routing algorithms; Design rule verification; Circuit Compaction; Circuit extraction and post-layout simulation Unit IV: CAD Tools for Automatic Test Program Generation; Combinational testing D-Algorithm and PODEM algorithm; Scan-based testing of sequential circuits; Testability measures for circuits Unit V: Modelling and synthesis: Linting Tools, Logic Synthesis, CAD Tools for Logic Synthesis, Gate-level simulation, Formal verification. CAD Tools for Physical Verification and LVS.			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Develop knowledge about CAD tools used for digital VLSI design, digital logic simulation, and physical design, including test and verification, and develop an understanding of FPGA CAD flow for design and implementation. CO2: Model digital systems at different levels of abstraction and simulate using Verilog HDL, CO3: Develop an understanding of automatic test program generation, testing algorithms, and simulate and test circuits. CO4: Apply their knowledge and skills to model and synthesize logic circuits, do formal verification, and transfer a design from a version possible to simulate to a version possible to synthesize			
Textbooks			

1. N.A. Sherwani, "Algorithms for VLSI Physical Design Automation ", 1999. 2. S.H. Gerez, "Algorithms for VLSI Design Automation ", 1998.4. J. Bhasker, "A VHDL Primer", AddisonWesley Longman Singapore Pte Ltd. 1992. 3. Drechsler, R., Evolutionary Algorithms for VLSI CAD, Kluwer Academic Publishers, Boston, 1998.
Reference Books
1. VERILOG HDL SYNTHESIS: A PRACTICAL PRIMER by J Bhaskar 2. Hill, D., D. Shugard, J. Fishburn and K. Keutzer, Algorithms and Techniques for VLSI Layout Synthesis, Kluwer Academic Publishers, Boston, 1989.

Course Code	Course Name	L – T – P	Credits
EE640	FPGA Architecture and Applications	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Understand the architecture, features, and programming of various programmable logic devices, including CPLDs and FPGAs.
- Analyze FPGA design flows, logic synthesis, routing, and technology mapping using industry-standard tools.
- Design and implement Finite State Machines (FSMs) and system-level digital designs on FPGAs.
- Apply FPGA-based design techniques to real-world digital systems and validate them using debugging tools.

Course Contents

Unit I: Programmable logic devices: ROM, PLA, PAL, CPLD, FPGA Features, Architectures, and Programming. Applications and Implementation of MSI circuits using Programmable Logic Devices.

Unit II: FPGAs: Field Programmable Gate Arrays- Logic blocks, routing architecture, design flow, technology mapping for FPGAs, Case studies Xilinx XC4000 & ALTERA's FLEX 8000/10000 FPGAs, Introduction to advanced FPGAs: Xilinx Virtex and ALTERA Stratix

Unit III: Finite state machines (FSM): Top-Down Design, State Transition Table, State assignments for FPGAs, Realization of state machine charts using PAL, Alternative realization for state machine charts using microprogramming, linked state machine, encoded state machine. FSM Architectures: Architectures Centered around non registered PLDs, Design of state machines centered around shift registers, One Hot state machine, Petrinets for state machines-Basic concepts and properties, Finite State Machine-Case study.

Unit IV: System level design: Controller, data path designing, Functional partition, Digital front end digital design tools for FPGAs. System-level design using mentor graphics/Xilinx EDA tool (FPGA Advantage/Xilinx ISE), Design flow using FPGAs.

Unit V: Case studies: Design considerations using FPGAs of parallel adder cell, parallel adder sequential circuits, counters, multiplexers, and parallel controllers. Debugging using Embedded Logic Analyzers.

Course Outcomes

On completion of this course, the students will be able to: CO1: Understand the architecture, programming, and applications of various Programmable Logic Devices (PLDs). CO2: Acquire fundamental knowledge on basic building blocks, routing architecture, and design flow of Field Programmable Gate Arrays (FPGAs) and advanced FPGAs. CO3: Apply skills to design Finite State Machines (FSMs) based on a state transition table and the realization of various state machines. CO4: Gain knowledge on the usage of different FPGA tools for data path, front-end, and system-level design using FPGAs. CO5: Develop skills in FPGA design considerations using sequential and combinational circuits and debugging using Logic Analysers.	
Text Books	
1. Field Programmable Gate Array Technology - S. Trimberger, Edr, 1994, Kluwer Academic Publications. 2. Engineering Digital Design - RICHARD F. TINDER, 2nd Edition, Academic press. 3. Fundamentals of logic design-Charles H. Roth, 4th Edition Jaico Publishing House.	
Reference Books	
1. Digital Design Using Field Programmable Gate Array, P.K. Chan & S. Mourad, 1994, Prentice Hall. 2. Field programmable gate array, S. Brown, R.J. Francis, J. Rose, Z.G. Vranesic, 2007, BS.	

Course Code	Course Name	L – T – P	Credits
EE641	VLSI Signal Processing	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the fundamentals of VLSI architectures for digital signal processing. • Learn techniques for designing high-speed, low-power, and area-efficient DSP systems. • Explore pipelining, parallelism, and retiming for performance optimization. • Develop skills in mapping DSP algorithms to hardware architectures. • Apply VLSI design concepts to real-time signal processing applications.			
Course Contents Unit I: An overview of DSP concepts: Linear system theory- DFT, FFT- realization of digital filters- Typical DSP algorithms- DSP applications- Data flow graph representation of DSP algorithm - Loop bound and iteration bound Retiming and its applications. Unit II: Algorithms for fast convolution: Algorithmic strength reduction in filters and transforms- DCT and inverse DCT- Parallel FIR filters- Pipelining of FIR filters- Parallel processing- Pipelining and parallel processing for low power. Unit III: Pipeline interleaving in digital filters: Pipelining and parallel processing for IIR filters- Low power IIR filter design using pipelining and parallel processing- Pipelined adaptive digital filters. Unit IV: Design of communication architectures for SOC: State variable description of digital filters- Round off noise computation using state variable description- Scaling using slow-down, retiming, and pipelining. Unit V: Adder and multiplier: Digital arithmetic, Fixed point and floating point. Fixed-point implementation of the FIR filter. IEEE 754 Floating point standards, Floating point arithmetic operations. Design of a floating-point adder and multiplier.			
Course Outcomes			

On completion of this course, the students will be able to: CO1: Realize the algorithm in the Data flow graph and Retiming and its applications CO2: Perform parallel processing and the pipelining concept of the FIR Filter CO3: Know the Pipelining in Adaptive Digital Filters CO4: Acquire knowledge of digital arithmetic and the design of fixed-point and floating-point adders and multipliers
Text Books
1. K. K. Parhi, VLSI Digital Signal Processing Systems, John-Wiley, 1999. 2. Pirsch, P., Architectures for Digital Signal Processing, Wiley, 1999.
Reference Books
1. Allen, J., Computer Architectures for Digital Signal Processing, Proceedings of the IEEE, Vol 73, No. 5, May, 1985 2. Bateman, A., and Yates, W., Digital Signal Processing Design, Computer Science Press, New York. 3. S.Y. Kung, H.J. White House, T. Kailath, VLSI and Modern Signal Processing, Prentice Hall, 1985.

Course Code	Course Name	L – T – P	Credits
EE642	SOC Design and Verification	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the chip design process. • Develop and design macros. • Gain expertise in SoC verification methodologies • Analyze and design communication architectures			
Course Contents Unit I: System on Chip Design Process: A canonical SoC Design, SoC Design flow, waterfall vs spiral, top-down vs bottom-up. Specification requirement, Types of Specification, System Design process, System level design issues, Soft IP Vs Hard IP, Design for timing closure, Logic design issues, Verification strategy, On-chip buses and interfaces, Low Power, Manufacturing test strategies. Unit II: Macro Design Process: Top-level Macro Design, Macro Integration, Soft Macro productization. Developing hard macros, Design issues for hard macros, Design, System Integration with reusable macros. Unit III: SOC Verification: Verification technology options, Verification methodology, Verification languages, Verification approaches, and Verification plans. System-level verification, Block-level verification, Hardware/software co-verification and Static net list verification. Unit IV: Design of Communication Architectures For SOCS: On-chip communication architectures, System-level analysis for designing communication, Design space exploration, Adaptive communication architectures, Communication architecture tuners, Communication architectures for energy/battery efficient systems. Introduction to bus functional models and bus functional model-based verification. Unit V: Verification architecture, Verification components, Introduction to VMM, OVM, and UVM.			
Course Outcomes			

On completion of this course, the students will be able to: CO1: Use different approaches to the chip design process and its requirements. Design issues, verification, and test strategies. CO2: Design and develop a macro and the issues regarding designing it. CO3: Know about technology, methods, and verification on different levels. CO4: Design communication architecture, design analysis, need for adaptable communication architecture, understanding of base models.
Text Books
1. “SoC Verification Methodology and Techniques”, Prakash Rashinkar Peter Paterson and Leena Singh. Kluwer Academic Publishers, 2001. 2. “Reuse Methodology manual for System on A Chip Designs”, Michael Keating, Pierre Bricaud, Kluwer Academic Publishers, second edition, 2001.
Reference Books
1. “Design Verification: Simulation and Formal Method based Approaches”, William K. Lam, Prentice Hall. 2. “System-on-a-Chip Design and Test”, Rochit Raj suman, ISBN. 3. “Multiprocessor Systems on chips”, A.A. Jerraya, W. Wolf, M K Publishers. 4. “The EDA Handbook”, Dirk Jansen, Kluwer Academic Publishers.

Course Code	Course Name	L – T – P	Credits
EE643	Digital Interface Design	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand digital interface design, develop, and design macros. • Develop skills in data converter interfacing gain expertise in SoC verification methodologies • Explore wireless and GPS interfacing techniques, analyze, and design communication architectures			
Course Contents Unit I: Introduction: Definition and Classification, Overview of Robots and Hardware Units in Robotics, Introduction to Zed Board Embedded Systems on a Chip (SoC), and the use of FPGA in Robotics Applications. State Machines and Applications. Unit II: Sensors and Actuators Interfacing: Sophisticated interfacing features in Devices/Ports, Timer and Counting Devices, ‘I2C’, ‘USB’, ‘CAN’. PWM in HW for robot control, LCD interfacing with FPGA. Unit III: Data Converters Interfacing: Introduction to ADC and DAC. Various Types and specifications, SPI interfacing in an FPGA. Unit IV & V: Wireless and GPS Interfacing: Introduction to Bluetooth- ZigBee Interface. Introduction to Gyro and accelerometer – Gyro accelerometer interface using Complementary Filter - Case study: Underwater Glider motion controller. NI Compact RIO embedded control hardware for rapid prototyping.			
Course Outcomes			

On completion of this course, the students will be able to: CO1: Understand the fundamentals of Digital Interface Design, including hardware units of basic Robotics. They will also learn about the Zed Board Embedded Systems on a Chip (SoC). CO2: Hands-on experience/Knowledge of the Sensor and Actuator Interface. They will also know various Sophisticated interfacing knowledge on Devices/Ports used in Robotics. CO3: Gain expertise in Data Converters Interfacing. They will also be able to understand various specifications regarding robotics. CO4: Get a working knowledge of Wireless and GPS interfacing. They will also be theoretically experienced in various Interfacing problems through the case study.
Text Books / Reference Books
1. Steve Kilts, Advanced FPGA Design: Architecture, Implementation, and Optimization, IEEE Press Wiley 2007. 2. Yale Patt and Sanjay Patel, Introduction to Computing Systems: From Bits and Gates to C and Beyond, 2nd edition, Publication Date: August 5, 2003 ISBN-10: 0072467509 ISBN-13: 978-0072467505. 3. Hamblen, James O., Hall, Tyson S., Furman, Michael D, Rapid Prototyping of Digital Systems: Springer 2008.

Course Code	Course Name	L – T – P	Credits
EE644	MIMO Communications	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand Fading Channels, Bit-Error Rate (BER) Analysis, and Multiple Antenna Systems - Develop skills in MIMO and Massive MIMO design. - Explore cognitive radio and be ready with the design			
Course Contents Unit 1: Introduction: Modern multi-user communication technologies, Principles of Wireless Communication, Fading Channels, Bit-Error Rate (BER) Analysis, Multiple Antenna Systems, Diversity concept, Cross-layer procedures: Link Adaptation, HARQ, Packet Scheduling and Radio Resource allocation for Best Effort and Real Time Traffic. Unit II: MIMO: Multiple-Input Multiple-Output (MIMO) Technology, MIMO signaling: Space Time coding, Diversity Multiplexing trade off, Multi-user MIMO and Network MIMO: Large MIMO; Small cells, relays and het-net (6); Green radio design considerations. MIMO Receivers, Multi-user MIMO, Beamforming, Precoding, Orthogonal Space Time Block Codes (OSTBC), Cooperative Communication, Optimal Combining, BER Analysis, and Diversity of Cooperative Communication, Optimal Power Allocation with Cooperation. Unit III: Massive MIMO: Introduction to Massive MIMO, Analysis with Perfect CSI, Channel Estimation in Massive MIMO, Analysis with Imperfect CSI, Multi-cell Massive MIMO and Pilot Contamination			

Unit IV: Schemes for 5G: New Modulation Schemes for 5G: Spatial Modulation (SM), Space shift keying, Generalized Spatial Modulation, Cooperative MIMO communication, Multi-Node Cooperation, AF and DF Protocols for Cooperation.	
Unit V: Cognitive radio: Introduction to Cognitive Radio Technology, OFDM for CR, Spectrum Sensing in Fading Wireless Channels, MIMO systems, OFDM systems, Cooperative Spectrum Sensing, Eigenvalue-based Spectrum Sensing, Multi-User Transmission in Interweave CR Systems, MIMO for Underlay CR Systems, Game Theory for Cognitive Radio, Spectrum Auctions.	
Course Outcomes	
On completion of this course, the students will be able to: CO1: Understand the Modern multi-user communication technologies CO2: Understand MIMO technology, coding, and diversity techniques CO3: Acquire knowledge of channel estimation in massive MIMO and analysis with imperfect CSI CO4: Gain knowledge of new modulation schemes for 5G CO5: Learn Cognitive radio technology, OFDM for CR, etc.	
Text Books/Reference Books	
1. Principles of Mobile Communications by G. Stuber, Springer, 2nd ed.. 2. Wireless Communications by A. Goldsmith, Cambridge. 3. Introduction to Space Time Wireless Communications by A. Paulraj, Nabar and Gore. 4. LTE, UMTS and The Long-Term Evolution by Sesia, Toufik and Baker 5. OFDM for Wireless Communications by R. Prasad. 6. UMTS for LTE by Holma and Toshala. 7. Adaptive PHY-MAC Design for Broadband Wireless Systems by R. Prasad, S. S. Das and Rahman. 8. Single and Multi-Carrier MIMO Transmission for Broadband Wireless Systems by R. Prasad, Rahman and S. S. Das.	

Course Code	Course Name	L – T – P	Credits
EE645	Adaptive Signal Processing	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamentals of adaptive filtering and the statistical concepts underpinning estimation and signal modeling. • Analyze random processes and their parametric models (AR, MA, ARMA) for designing optimal FIR filters. • Understand and implement the LMS algorithm and its variants, including convergence behavior and limitations. • Develop and apply RLS algorithms and their variants for real-time adaptive filtering. • Apply adaptive filtering techniques to practical problems such as channel equalization, echo and interference cancellation, and beamforming.			

Course Contents Unit I: Basic Principles of Adaptive Filtering: Estimation; probability, random variables, conditional and joint probability densities, statistical independence, correlation and covariance, Complex random variables, random vectors, correlation and covariance matrices, properties of Hermitian matrices (e.g., correlation/covariance matrices), positive definite forms. Unit II: Random Process: Multivariate Gaussian density. Concepts of random processes, wide-sense stationary (WSS) processes and their correlation structures, power spectral density, parametric modelling of WSS processes – AR, MA, and ARMA processes. Optimal FIR filters, real and complex valued optimal filters, method of steepest descent. Unit III: Least Mean Square (LMS) Algorithm: Convergence of LMS algorithm; normalized LMS, affine projection, Limitations of LMS algorithm. Unit IV: Recursive Least Squares: Formulation of recursive least squares (RLS) based adaptive filters, Moore-Penrose pseudo inverse, matrix inversion lemma, Development of the RLS transversal adaptive filter, properties, variants of the RLS family. Unit V: Channel Characterization: Examples of adaptive filters: channel equalization, echo cancellation, interference cancellation, line enhancement, beamforming, etc.
Course Outcomes On completion of this course, the students will be able to: CO1: Learn the basic principles of adaptive filtering: estimation, probability, random variables, conditional and joint probability densities, statistical independence, correlation, and covariance. CO2: Understand the concepts of random process: multivariate Gaussian density. concepts of random processes, wide-sense stationary (WSS) processes and their correlation structures, power spectral density, parametric modelling of WSS processes – AR, MA, and ARMA processes. CO3: Learn the basics of the least mean square (LMS) algorithm. CO4: Apply knowledge and skills to visualize the Formulation of recursive least squares (RLS) based adaptive filters. CO5: Acquire knowledge of channel characteristics.
Text Books/Reference Books 1. Bernard Widrow and Samuel D. Stearns, Adaptive Signal Processing, Person Education, 2005. 2. Simon Haykin, Adaptive Filter Theory, Pearson Education, 2003. 3. John R. Treichler, C. Richard Johnson, Michael G. Larimore, Theory and Design of Adaptive Filters, Prentice-Hall of India, 2002 4. S. Thomas Alexander, Adaptive Signal Processing - Theory and Application, Springer Verlag. 5. D. G. Manolokis, V. K. Ingle and S. M. Kogar, Statistical and Adaptive Signal Processing, Mc Graw Hill International Edition, 2000.
Reference Books 1. Ali H. Sayed, Fundamentals of Adaptive Filtering, Wiley, 1st Ed., 2003. 2. Farhang-Boroujeny B., Adaptive Filters Theory and Applications, John Wiley & Sons, 1st Ed., 1998. 3. Mohamed Ibnkahla (Edited), Adaptive Signal Processing in Wireless Communications, CRC Press, Taylor & Francis Group, 1st Ed., 2009. 4. "Adaptive Filters", S. Haykin, Prentice-Hall India 5. "Adaptive Filters", A. H. Sayed, Wiley-Interscience, New York, USA

Course Code	Course Name	L – T – P	Credits
EE646	Artificial Intelligence for Embedded Systems	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the principles of machine learning, including supervised, unsupervised, semi-supervised, and reinforcement learning, with practical implementation. • Develop an understanding of probability, statistics, and scientific computing tools in Python for AI model development and data analysis. • Enable students to design, train, and deploy TinyML models on embedded platforms and microcontrollers for real-time applications. • Impart knowledge of AI-based embedded applications such as audio classification, wake-word detection, person detection, and gesture recognition using TensorFlow Lite.			
Course Contents Unit I: Introduction to Machine Learning: Machine Learning, Aspects of Machine Learning, Machine Learning Application, Linear Regression, Correlation, Regression Analysis of. Supervised and Unsupervised Learning, Supervised Learning Model, UnSupervised Learning Model, Semi Supervised Learning, comparison, Case Study. Reinforcement Learning: Reinforcement Learning model, Markov Decision Problem, Q-Learning, Temporal Decision Learning, Learning Automata, Case Study, Clustering: k-means, Fuzzy, Hierarchical, Similarity, Machine Learning programming for Supervised and Unsupervised Learning models Unit II: Probability and Statistics with Introduction to Python: Introduction to Probability and Statistics, Need for Probability and Statistics, First Order Linear Model, Least Square Regression Line Model, Introduction to Scientific, Libraries in Python-NumPy, Introduction to Scientific Libraries in Scipy, Estimated Coefficients, Problems related to linear model, Importing dataset using Pandas, Altering dataset using Pandas, Selection Operator, Plotting Libraries, Introduction and basic analysis using ScikitLearn, Introduction to Keras, Introduction to Tensor Flow, Programming in Basic Mathematical and Scientific Operations using NumPy & SciPy, Analysis of a Dataset (CSV) using Pandas with plots, Basic Mathematical Operations using Keras and Tensor flow. Unit III: Tiny ML in an embedded platform: Building and Training a Model, Applications, Deploying to Microcontrollers, building on embedded Microcontroller model, training our model, Converting the model for Tensor Flow Lite, SparkFun edge, ST Microelectronics. Model Training in Edge Impulse, deploy a Trained Model to embedded platform, Anomaly Detection, Programming to Model Deploying in Arduino Microcontrollers Unit IV: Audio classification & Wake-Word Detection: Audio classification and Keyword Spotting. Audio Data Capture, Audio Feature Extraction (MFCC), Implementation Strategies and Sensor Fusion, CNN training for sound classification, application Architecture, Walking Through the test, listening for wake words, Deploying to Microcontrollers, Training the New model, Using the model in the project, Training with own Data. Person Detection: Building an Application, Training Model Programming Arduino Tensor Flow Lite applications Unit V: Magic Wand: Magic Wand Building an Application, Training Model, TensorFlow Lite for Microcontrollers, Designing TinyML Applications, Training a model in Magic wand			
Course Outcomes			
On completion of this course, the students will be able to:			
CO1: Understanding the fundamentals of machine learning			

CO2: Understanding Python concepts for probability and statistics CO3: Learn training model construction and implement a trained ML model on an embedded platform CO4: Understand and implement wake word detection with the help of the architecture. CO5: Learn & apply the knowledge to develop the model for the given application on an embedded platform
Text Books/ Reference Books
1. Wes McKinney, “Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython”, Second Edition, O’reilly Media, Inc., First Edition, 2018. 2. Machine Learning: a practitioner's approach, Chandra S.S., Vinod, Hareendran S., Anand, PHI Learning pvt. ltd., 2021 3. TinyML_ Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power 4. Microcontrollers- Pete Warden, Daniel Situnayake -O'Reilly Media (2019) 5. https://www.coursera.org/learn/introduction-to-embedded-machinelearning# syllabus 6. https://sites.google.com/g.harvard.edu/tinyml/home 7. https://www.udemy.com/course/getting-started-with-embedded-ai-hands-onexperience// 8. Trevor Hastie, Robert Tibshirani, Jerome Friedman, “The Elements of Statistical Learning: Data Mining, Inference, and Prediction”, Second Edition, Springer, 2009. 9. Pete Warden, Daniel Situnayake, “TinyML: Machine Learning with TensorFlow Lite on Arduino and Ultra-Low-Power Microcontrollers”, O'Reilly Media; 1st edition (16 December 2019) 10. Christopher M. Bishop, “Pattern Recognition and Machine Learning”, Springer, 2nd edition 2011. 11. Tom M. Mitchell, “Machine Learning”, McGraw-Hill, 1st edition 1997.

Course Code	Course Name	L – T – P	Credits
EE647	RF Photonics	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Impart knowledge about RF Photonic. • Introduce RF Signal Generation & Detection. • Impart the knowledge of Photonics Signal Processing. • Provide practical knowledge of Applications of RF Photonics.			
Course Contents Unit I: Introduction to RF and photonic systems: Introduction to microwave photonics, basic optical and RF components: sources, modulators, receivers, passive devices, RF mixers, wireless receivers; applications of microwave photonics, fibre/wireless links: basic configuration, signal generation, transport strategies, design and analysis, advantages and limitations, high-speed optical wireless links, multiple coherent photonic RF system operations, optically controlled phased array antennas.			

Unit II: RF Signal generation and detection: Optoelectronic oscillators (generation, frequency combs); microwave photonic integrated circuits (different platforms of integration, filter designs, micro resonators, nonlinear effects), photonic-based tunable RF filter, multiple RoF and multiple RoFSO, CW, Pulsed, and FMCW signal generation and detection photonic system assembly, stretch processing, Dual and multiband operations, photonics detectors for RF regeneration, PHODIR architecture.

Unit III: Photonics signal processing: Microwave photonics signal processing: filters, photonics analog-digital-converters, true-time delay beamforming, electro-optic sampling, sampling signal generation, direct digitalization, optical vector mixing, RF down conversion, Photonic-assisted microwave channelization (SDM, WDM, TDM), far-field/near-field AoA measurement, Ultra-Wideband free space beamforming, SLM, optical PLL operation, wideband Programmable Microwave Photonic Signal Processing, Reconfigurable photonics,

Unit IV: Microwave M/MS using photonics: Microwave measurements, Electronics solutions and challenges, Introduction to photonics-based broadband microwave measurements, signal parameter measurement-electric field, Phase Noise, Spectrum Analysis, Instantaneous Frequency, IF based microwave/optical power monitoring, Multiple-Frequency Measurement Based on Frequency to-Time Mapping, Doppler Frequency Shift Estimation, measurements of other signal parameters (Time–frequency analysis, Compressive sensing for a spectrally sparse signal), Software-defined solutions for photonic microwave measurements.

Unit V: Contemporary applications of microwave photonics: Fully Photonic based radar, single photonic multiband software defined radar, SAR/ISAR imaging, quantum radar, THz generation, sensing/imaging and beamforming, LIDAR systems, Fiber/FSO- connected Distributed Radar System, Distributed MIMO chaotic radar based on WDM technology, Microwave Passive Direction Finding, STAR, Integrated Photonic Beamforming Architecture for Phased-Array Antennas, Future multifunctional photonics radar concepts, microwave photonics architecture for modern ultra-wide bandwidth wired/wireless communications.

Course Outcomes

CO1: Understand the fundamentals of microwave-photonics and have a brief idea of opto-electronic components (sources, modulators, receivers, etc.)

CO2: Learn about the photonic integrated circuits, tunable RF filters design, photonics-based pulsed and FMCW RF exciter, and multiband radar.

CO3: Acquire knowledge of microwave photonics signal processing, like filters, ADC, delay, sampling, photonic measurements, ultra-wideband free space beamforming, etc.

CO4: Understand the concept of photonics-based broadband microwave measurements, signal parameter measurement- electric field, Phase Noise, Spectrum Analysis, Instantaneous Frequency, and time-frequency analysis

CO5: Gain knowledge of full photonics radar, SAR/ISAR imaging, LIDAR systems, Fibre/FSO-connected Distributed Radar System

Course Code	Course Name	L – T – P	Credits
EE648	VLSI Fabrication Technology	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Understand semiconductor materials and crystal growth processes.
- Learn wafer fabrication steps, including oxidation, lithography, diffusion, and deposition.
- Study etching, doping, and metallization techniques for IC fabrication.
- Explore cleanroom practices and process integration for VLSI manufacturing.
- Gain insight into advanced fabrication technologies and scaling trends.

Course Contents

Unit I: Overview and materials:

Introduction to microelectronic fabrication.

Semiconductor substrate: Phase diagram and solid solubility, Crystal structure, Crystal defects, Crystal growth.

Unit II: Hot processing and ION implantation:

Diffusion: Atomistic models of diffusion, Analytic solutions of Fick's law, Diffusion coefficients, Two-step diffusion, Diffusion system.

Thermal Oxidation: The Deal-Grove model, the initial oxidation, Oxide characterization, oxidation-induced stacking faults, Oxidation systems.

Ion implantation: Ion implantation system, Vertical projected range, Channeling effect, Implantation damage, Problems, and concerns.

Unit III: Pattern transfer:

Optical lithography: Overview, Source systems, Contact/proximity printers. Projection printers, Alignment.

Photoresist: Contrast curves, applying and developing photoresist.

Etching: Wet etching, Plasma etching, Ion milling, Reactive ion etching, Liftoff. Electron

Beam Lithography: Overview, Types of electron beam lithography, Patterning Strategies, Electron beam lithography process.

Unit IV: Thin film deposition and characterization techniques:

Physical Vapor Deposition: Evaporation Systems, Sputtering Systems.

Chemical Vapor Deposition: CVD system, Advanced CVD systems.

Epitaxial growth: Wafer cleaning and native oxide removal, thermal dynamics, Surface reactions, Dopants, Defects in epitaxial growth, MOCVD, MBE, and CBE. Characterization

Techniques: XRD, FESEM, TEM, AFM, Raman Spectroscopy, Spectroscopic Ellipsometry, UV-Vis Measurement, Hall Measurement, CV and IV measurement.

Unit V: Process integration:

Contacts and metallization: Junction and oxide isolation, Si on insulator, Schottky and Ohmic contacts, Multilevel metallization.

CMOS technologies: Device behavior, Basic 3 μm technologies, Device scaling. Circuit Manufacturing: Yield, Particle control, Design of experiments, Computer integrated manufacturing.

Course Outcomes

On completion of this course, the students will be able to:

CO1: Understand the various materials in the Crystal Level.

CO2: Understand the Ion Implantation, Diffusion, and various fabrication processes of IC

CO3: Learn the thin film deposition and characterization techniques
CO4: Gain knowledge of various process integration
Text Books/Reference Books
1. Stephen A. Campbell, The Science and Engineering of Microelectronic Fabrication, 2nd edition (Oxford University Press, 2001).

Course Code	Course Name	L – T – P	Credits
EE650	Semiconductor Devices for High-Speed and High-Power Applications	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Understand performance-limiting parameters in high-speed and high-power semiconductor devices.
- Explore the material properties and processing of III–V and wide bandgap semiconductors for advanced applications.
- Analyze current transport mechanisms and characteristics of Schottky and MOS devices.
- Study the operation and advantages of MESFETs, HEMTs, HBTs, and GaN-based devices in high-frequency domains.

Course Contents

Unit I: Review: performance parameters of high-speed devices and circuits: Introduction, basic concepts, transit time of charge carriers, junction capacitances, on-resistances and their dependence on the device geometry and size, carrier mobility, doping concentration and temperature; contact resistance and interconnection/interlayer capacitances, SOI, ECL.

Unit II: Materials requirement for high-speed devices and circuits: III –V binary and ternary compound semiconductors (GaAs, InP, InGaAs, AlGaAs etc.), silicon-germanium alloys and silicon carbide for high-speed devices, as compared to silicon-based devices; crystal structure, dopants and electrical properties such as carrier mobility, velocity versus electric field characteristics of these materials; material and device process technique for III-V and IV – IV semiconductors.

Unit III: Physical phenomena governing metal semiconductor contacts and metal insulator semiconductor, and MOS devices:

Metal semiconductor contacts, interface state density, Schottky barrier diode; thermionic Emission model for current transport and current-voltage (I-V) characteristics; effect of interface states and interfacial thin electric layer on the Schottky barrier height and the I-V characteristics.

Unit IV: MESFETs, HEMTs, HBTs: Pinch off voltage and threshold voltage of MESFETs; D.C. characteristics; velocity overshoot effects; sub-threshold characteristics, short channel effects, hetero-junction devices; MODFET- principle of operation and the unique features of HEMT, InGaAs/InP HEMT; HBT principle of operation, its benefits, GaAs and InP based HBT, the surface passivation for stable high gain high frequency performance, strained layer devices.

Unit V: III-Nitride HEMTs: GaN comparison with other materials, physics of group III-Nitrides, GaN HEMTs, GaN-based devices issues and solutions.

Course Outcomes

On completion of this course, the students will be able to:

CO1: Understand the performance parameters of high-speed devices and circuits, and materials required for high-speed devices

CO2: Understand the fundamentals of physical phenomena in MIS, MOS devices for high-speed applications

CO3: Gain knowledge of HEMTs, HBTs

CO4: Acquire knowledge of the latest technology in high-speed and high-power III-nitride HEMTs and their application in various domains

Text Books/Reference Books:	
1.	H. Beneking, High Speed Semiconductor Devices: Circuit aspects and fundamental behavior, Chapman and Hall, London, 1994.
2.	C. Y. Chang & F. Kat, GaAs High Speed Devices: Physics, Technology and Circuit Applications, Wiley, NY 1994.
3.	S. M. Sze, High Speed Semiconductor Devices, Willey, 1990.
4.	Michael Shur, GaAs Devices and Circuits, Plenum Press, NY, 1987.
5.	N. G. Einsprush and R. Weisseman, VLSI Electronics: GaAs Microelectronics, Academic Press, NY, 1985.
6.	S. K. Ghandhi, VLSI Fabrication Principles, Wiley, NY, 1994.

Course Code	Course Name	L – T – P	Credits
EE653	Quantum Transport in Nanoscale FETs.	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand quantum transport principles and atomistic models governing nanoscale FETs. - Analyze energy bands, density of states, and quantum effects in low-dimensional systems. - Learn self-consistent solutions of Schrödinger's equation and their application in nano- devices. - Study NEGF formalism and transport mechanisms in coherent and non-coherent regimes of 2D FETs.			
Course Contents Unit I: Preliminary concepts of atomistic view: Introduction, Energy level diagram, electrons flow, quantum of conductance formula, ballistic conductance, diffusive conductance, coulomb blockade, angular averaging, Drude formula, Ohm's law. Unit II: Energy band: $E(p)$ or $E(k)$ relation, density of states, number of modes, electron density (n), quantum wells, wires, dots, nanotubes, conductivity vs. electron density (n), quantum capacitance, the nano transistor boundary condition, Quasi-Fermi Levels (QFL's), Landauer formulas, electrostatic potential, Boltzmann Equation, Spin Voltages. Unit III: Schrodinger equation self-consistent solution: Hydrogen atom, method of finite differences, wave equation, differential to matrix equation, dispersion relation, counting states, Beyond 1–D, Basis functions, Graphene, Reciprocal Lattice / Valleys, self-consistent field (SCF) procedure. Unit IV: Non-equilibrium green's function (NEGF) formalism: Semiclassical model, quantum model, equations, current operator, scattering mechanisms, transmission, resonant tunneling, dephasing, local density of states [LDOS]. Unit V: Coherent and non-coherent transport in 2D FETs: Density matrix, Inflow/outflow, quantum point contact, self-energy, surface Green's function, graphene, Fermi-Golden Rule, inelastic scattering.			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Understand the wave-particle duality nature of electrons, energy quantization, Hamiltonian, etc. CO2: Understand the Schrodinger equation, graphene structure, self-consistent field (SCF) procedure for device simulations with quantum effects CO3: Gain knowledge of NEGF with scattering parameters for realistic nano transistor simulations CO4: Acquire knowledge of non-ideal effects present in nanoscale FETs, different types of scattering effects, etc.			

Text Books/Reference Books	
1. Supriyo Duttai, Quantum Transport Atom to Transistor, 5th edition, Cambridge University Press, 2005. 2. Mark S. Lundstrom, Jing Guo, Nanoscale transistors Device physics, modelling and simulation, Springer, 2006. 3. Supriyo Dutta, Electronic Transport in Mesoscopic Systems, Cambridge University Press, 1995. 4. Roger T Howe, Charles G Sodini, Microelectronics An integrated approach, Pearson education. 5. Behzad Razavi, Fundamentals of Microelectronics, John Wiley India Pvt. Ltd, 2008. 6. Sundaram Natarajan, Microelectronics – Analysis and Design, Tata McGraw-Hill, 2007.	

Course Code	Course Name	L – T – P	Credits
EE 654	Introduction to Space Technology	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Develop an understanding of Space fundamentals • Provide knowledge of spacecraft configuration and structural design. • Equip students with knowledge of space communication • Introduce space power systems and thermal control			
Course Contents Unit I: Space fundamentals: Introduction, orbital mechanics, the atmosphere, orbit determination, gravity, engineering of Space systems, basics of astronomy, and management of space systems. Unit II: Spacecraft configuration and structural design: Introduction, Design interfaces and concepts, launch vehicles, structural design and test criteria, structural dynamics, structural test verifications, quality & reliability engineering, and fabrication & test processes and standards. Unit III: Space communication: Introduction and overview, Propagation of Radio waves, modulation, noise, link budget, remote sensing, and geospatial technologies. Unit IV: Space environment and space missions: Earth's atmosphere, solar radiation, mission analysis and planning, telemetry tracking and command stations, prelaunch operations, launch operations, and postlaunch operations. Unit V: Space power systems and thermal control: The space environment, energy sources, solar cell arrays, energy storage devices, space power systems, environmental variations, and thermal control.			
Course Outcomes			
After completing this course, the students will be able to: CO1: Acquire knowledge of broad and multidisciplinary knowledge in space technology CO2: Understand satellite orbits, satellite-to-ground links, and link budgets CO3: Understand launch vehicle design, earth observation, navigation, and communication modules CO4: Learn about the space environment, Earth's atmosphere, missions, and launch operations CO5: Understand Space Power Systems and Thermal Control			
Text Books			

1. Vincent L. Pisacane and Robert C. Moore, Fundamentals of Space Systems, Oxford University Press, USA, 1994. 2. Thomas F. Mütsch and Matthias B. Kowalski, Space Technology: A Compendium for Space Engineering, De Gruyter Oldenbourg, Germany, 2016.
Reference Books
1. Wilfried Ley, Klaus Wittmann, and Willi Hallmann, Handbook of Space Technology, Wiley Blackwell, New Jersey, USA. 2. Ignacio Chechile, Space Technology: A Short Introduction, Springer International Publishing AG, 2023.

Course Code	Course Name	L – T – P	Credits
EE655	IC Design: RTL to GDS implementation	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand the complete VLSI design flow from RTL coding to GDSII generation. - Explore RTL modeling, synthesis, verification, and logic optimization techniques. - Analyze timing, power, testability, and physical constraints in IC design. - Gain practical knowledge of chip planning, placement, routing, and sign-off processes.			
Course Contents Unit I: Basic Concepts -VLSI Design Flow : Basic Concepts of Integrated Circuit: Structure, Fabrication, Types, Design Styles, Designing vs. Fabrication, Economics, Figures of Merit Overview of VLSI Design Flow: Design Flows and Abstraction; Pre-RTL Methodologies: Hardware-software Partitioning, SoC Design, Intellectual Property (IP) Assembly, Behavioral Synthesis, Overview of VLSI Design Flow: RTL to GDS Implementation: Logic Synthesis, Physical Design; Verification and Testing; Post- GDS Processes Unit II: Hardware Modeling, RTL synthesis & Optimization: Introduction to Verilog Functional verification using simulation: testbench, coverage, mechanism of simulation in Verilog, RTL Synthesis: Verilog Constructs to Hardware Logic Optimization: Definitions, Two-level logic optimization, Logic Optimization: Multi-level logic optimization, FSM Optimization Formal Verification: Introduction, Formal Engines: BDD, SAT Solver. Unit III: Verification & STA: Formal Verification: Model Checking, Combinational Equivalence Checking Technology Library: Delay models of Combinational and Sequential Cells, Static Timing Analysis: Synchronous Behavior, Timing Requirements, Timing Graph, Mechanism, Delay Calculation, Graph-based Analysis, Path-based Analysis, Accounting for Variations. Unit IV: Constraints & DFT: Clock, I/O, Timing Exceptions Technology Mapping, Timing-driven Optimizations. Power Analysis, Power-driven Optimizations Design for Test: Basics and Fault Models, Scan Design Methodology, Design for Test: ATPG, BIST Basic Concepts for Physical Design: IC Fabrication, FEOL, BEOL, Interconnects and Parasitics, Signal Integrity, Antenna Effect, LEF files. Unit V: Chip Planning: Partitioning, Floorplanning, Power Planning Placement: Global Placement, Wirelength Estimates, Legalization, Detailed Placement, Timing-driven Placement, Scan Cell Reordering, Spare Cell Placement, Clock Tree Synthesis: Terminologies, Clock Distribution Networks, Clock Network Architectures, Useful, Skews Routing: Global and Detailed, Optimizations Physical Verification: Extraction, LVS, ERC, DRC, ECO and Sign-off			

Course Outcomes
On completion of this course, the students will be able to: CO1: Develop basic concepts of VLSI design Flow CO2: Understand Hardware Modelling and RTL synthesis CO3: Design and verify digital circuits and do static timing analysis CO4: Develop a different Design for Test CO5: Understand and develop the chip partitioning and floor planning.
Text Books/Reference Books
1. Introduction to VLSI Design Flow, Sneh Saurabh 2. N.A. Sherwani, "Algorithms for VLSI Physical Design Automation ", 1999. 3. VERILOG HDL SYNTHESIS: A PRACTICAL PRIMER by J Bhaskar 4. "Design Verification: Simulation and Formal Method based Approaches", William K. Lam, Prentice Hall. 5. "The EDA Hand Book", Dirk Jansen, Kluwer Academic Publishers.

Course Code	Course Name	L – T – P	Credits
EE656	IC Testing & Verification	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Introduce the VLSI design flow with emphasis on fault models, simulation techniques, and verification strategies.
- Develop an understanding of functional and structural testing methodologies, including fault modeling, fault simulation, and test pattern generation.
- Enable students to apply sequential machine testing techniques and address challenges in deep submicron ICs and quiescent current testing.
- Impart knowledge of design-for-testability (DFT) approaches, built-in self-test (BIST), formal verification, and on-line testing methods.

Course Contents

Unit I: Design Flow of VLSI Systems: (1) Design and manufacturing defect models (2) Simulation-based design verification. Fault Simulation: (1) Parallel (2) Deductive (3) Concurrent

Unit II: Functional Testing Methodologies: (1) Exhaustive testings (2) Pseudo-exhaustive testing structure Based Testing: (1) Fault model-based testing: (A) Stuck-at faults; (B) Bridging faults; (C) Stuck-open faults; (D) Delay faults (2) Fault Grading (3) Automatic Test Pattern Generation Algorithms: (A) D-Algorithms; (B) PODEM; (C) FAN, etc.

Unit III: Sequential Machine Testing: (1) Machine identification experiments (2) Modified PODEM and D-algorithms Quiescent Current Testability Methods; deep submicron challenges

Unit IV: Design for Testability Methods: (1) Testable combinational/sequential circuits (2) Scan path design (3) Partial scan (4) Built-in Self Test (BIST) (5) Data compaction techniques

Unit V: Introduction to Formal Design Verification

On-Line Testing Methods: (1) Self-checking circuits (2) Error detecting/correcting codes.

Course Outcomes

On completion of this course, the students will be able to:

- CO1:** Understand the fundamentals of Design for Testability (DFT) concepts.
- CO2:** Understand built-in self-test (BIST) architectures
- CO3:** Perform Fault modeling, ATPG (Automatic Test Pattern Generation), scan chain design
- CO4:** Acquire knowledge of Verification methodologies, including simulation
- CO5:** Understand formal verification and emulation

Text Books/References Books
1. “SystemVerilog for Design”: A Guide to Using SystemVerilog for Hardware Design and Modeling Sutherland, Stuart, Davidmann, Simon, Flake, Peter 2nd ed., 2006 2. “SystemVerilog for Verification”: A Guide to Learning the Testbench Language Features, Chris Spear, 2006 3. “Hardware Verification with System Verilog”: An Object-Oriented Framework Mintz, Mike, Ekendahl, Robert 2007 4. Introduction to VLSI Design Flow, Sneh Saurabh 5. N.A. Sherwani, “Algorithms for VLSI Physical Design Automation ”, 1999. 6. VERILOG HDL SYNTHESIS: A PRACTICAL PRIMER by J Bhaskar 7. “Design Verification: Simulation and Formal Method based Approaches”, William K. Lam, Prentice Hall. 8. “The EDA Hand Book”, Dirk Jansen, Kluwer Academic Publishers.

Course Code	Course Name	L – T – P	Credits
EE657	Low Power & High-Speed Analog Design	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the fundamentals of low-power and high-speed analog circuit design. • Learn design techniques for high-speed amplifiers, comparators, and data converters. • Analyze trade-offs between power, speed, noise, and area in analog circuits. • Explore design challenges in deep-submicron CMOS technologies. • Gain hands-on experience in optimizing analog and mixed-signal circuits. • Apply concepts to real-world applications like wireless, biomedical, and high-speed I/O systems.			
Course Contents Unit I: Fundamentals of Low Power & High-Speed Analog Circuits: Introduction & Motivation: Understanding the necessity for low-power and high-speed circuits in modern integrated circuits (ICs). Trade-offs & Performance Metrics: Exploring power, speed, gain, noise, linearity, and area considerations. Technology Scaling & Challenges: Addressing short-channel effects, leakage power, and process variations. MOSFET Basics Revisited: weak inversion, subthreshold operation, and the gm/Id design approach. Design Constraints in CMOS: Focusing on low-power and high-speed design within CMOS technology. Unit II: Low Power Design Techniques Sources of Power Dissipation: Identifying dynamic, static, short-circuit, and leakage power. Subthreshold & Weak Inversion Design: Applying the gm/Id methodology. Low-Power Biasing Circuits: Designing current mirrors and bandgap references. Low-Voltage Opamps & Comparators: Exploring Class AB, bulk-driven, and dynamic			

biasing techniques. Power Reduction Techniques: Implementing power gating, body biasing, and adaptive voltage scaling Unit III: High-Speed Design Techniques High-Speed Amplifiers: Studying folded cascode, current-mode circuits, and active feedback. High-Speed Comparators: Designing dynamic comparators and sense amplifiers. Bandwidth Enhancement Techniques: Utilizing inductive peaking and negative capacitance. Current-Mode Signalling: Facilitating low-power high-speed data transfer. High-Speed Switched-Capacitor Circuits: Implementing efficient designs. Unit IV: Low-Power & High-Speed Data Converters and Clocking Data Converter Fundamentals: ADC/DAC performance metrics. Low-Power ADC Architectures: SAR, $\Sigma\Delta$, and pipeline ADCs. High-Speed ADC Architectures: Flash and time-interleaved ADCs. Clocking Techniques: PLLs and DLLs for high-speed systems. Jitter and Phase Noise: Low-power clock generation challenges. Unit V Case Studies, Industry Trends & Practical Design Industry Case Studies: Analyzing low-power, high-speed analog ICs. Power Management: Strategies for high-speed circuits. Mixed-Signal Design Challenges: Addressing contemporary issues. Emerging Technologies: AI-assisted design, Fin-FETs, and SOI CMOS.
Course Outcomes
On completion of this course, the students will be able to: CO1: Understand the fundamentals of low-power & high-speed analog circuits CO2: Choose the appropriate low-power design techniques CO3: Acquire knowledge of high-speed design techniques CO4: Understand Low-Power & High-Speed Data Converters and Clocking CO5: Analyze the case studies, Industry Trends & Practical Design
Text Books/Reference Books
1. CMOS Analog Circuit Design by P.E. Allen & D.R. Holberg 2. Design of Analog CMOS Integrated Circuits by Behzad Razavi 3. Analysis and Design of Analog Integrated Circuits by P.R. Gray, P.J. Hurst, S.H. Lewis, R.G. Meyer 4. Low Power Design Methodologies by J. Rabaey 5. Low-Power CMOS Circuits: Technology, Logic Design, and CAD Tools by C. Piguet 6. Phase-Locking in High-Performance Systems – B. Razavi

Course Code	Course Name	L – T – P	Credits
EE658	Hardware Accelerators	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the RISC-V instruction set architecture and simulation tools. • Understand pipelining, out-of-order execution, and multicore CPU design. • Study memory hierarchies, coherence, and consistency models. • Explore GPU architectures, vector and array processing systems. • Develop architectural understanding for machine learning and accelerator design.			
Course Contents Unit I: Intro to RISC V ISA, covering all Instructions of Integer ISA, simulating sample programs using spike RISC V ISA simulator Unit II: Pipelining, Out-of-order processors, MULTI CORE CPUS Unit III: Caches, main memory, Memory coherence and consistency Unit IV: GPUS, VECTOR PROCESSING, ARRAY PROCESSING, SYSTOLIC ARRAYS Unit V: On-chip networks, Heterogenous design concepts, Accelerator design, interfacing			

accelerator with processor core, HLS etc. Architecture for machine learning.
Course Outcomes
On completion of this course, the students will be able to: CO1: Understand the fundamentals of RISC-V and its ISA CO2: Develop the concepts of Pipelining, Multicore CPUs CO3: Grasp the Knowledge of memory in CPUs CO4: Learn about the important GPU processors and their processing units CO5: Develop the understanding and design of an architecture for machine learning.
Textbooks
1. Advanced Computer Architecture by Smruti R Sarangi Jul 21, 2021
Reference Books
1. Advanced Computer Architecture by Smruti R Sarangi Jul 21, 2021 2. RISC V READER BY DAVID PATTERSON 3. Computer Organization and Design RISC-V Edition: The Hardware Software Interface (The Morgan Kaufmann Series in Computer Architecture and Design)

Course Code	Course Name	L – T – P	Credits
EE659	MEMS and Microsystems Design	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Introduce the fundamentals of MEMS technology, key application domains, and the influence of scaling laws on microsystem design. - Develop an understanding of materials, micromachining techniques, and thin film deposition processes used in MEMS fabrication. - Enable students to model and design MEMS devices using analytical and finite element methods. - Explore various microactuators, microsensors, and real-world MEMS applications through case studies and emerging trends in smart systems and IoT.			
Course Contents Unit I: Introduction to MEMS and Microsystems: Overview of MEMS Technology, Applications of MEMS in Automotive, Biomedical, and Consumer Electronics, Scaling Laws and Microsystem Design Considerations.			

Unit II: MEMS Materials and Fabrication: Materials for MEMS (Silicon, Polymers, Metals), Bulk Micromachining and Surface Micromachining, Thin Film Deposition Techniques	
Unit III: MEMS Design and Modeling: Design Methodologies for MEMS Devices, Finite Element Modeling and Simulation, Analytical Modeling Techniques	
Unit IV: Microelectromechanical Systems: Microactuators (Electrostatic, Piezoelectric, Thermal), Micro Sensors (Pressure, Accelerometers, Gyroscopes), RF MEMS Devices	
Unit V: Case Studies and Applications: Design Case Studies in MEMS, Emerging Trends in MEMS Technology, MEMS in IoT and Smart Systems	
Course Outcomes	
On completion of this course, the students will be able to: CO1: Understand the fundamentals of MEMS technology CO2: Develop an understanding of MEMS materials and fabrication CO3: Learn concepts related to the design methodologies of MEMS CO4: Learn about MEMS devices and actuators CO5: Understand current trends in the MEMS industry	
Text Books/References Books	
1. "Microsystem Design" by Stephen D. Senturia, Springer. 2. "Fundamentals of Microfabrication" by Marc Madou, CRC Press. 3. "MEMS and Microsystems: Design and Manufacture" by Tai-Ran Hsu, McGraw Hill. 4. "The MEMS Handbook, MEMS introduction and Fundamentals, Mohammed Gad el Hak 5. The MEMS Handbook, MEMS Design and Fabrication, Mohammed Gad el Hak 6. The MEMS Handbook, MEMS Applications, Mohammed Gad el Hak Foundations of MEMS, Chang Liu 7. Handbook of Silicon based MEMS Materials and Technologies, Veikko Lindroos, Markku Tilli, Ahri Lehto, Teruaki Motooka	

Course Code	Course Name	L – T – P	Credits
EE660	MEMS Sensors and Actuators	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Introduce the classification, performance parameters, and integration aspects of sensors and actuators in MEMS systems. - Develop an understanding of the design, operation, and simulation of mechanical, thermal, optical, and magnetic MEMS-based sensors and actuators. - Explore the principles and applications of chemical, biomedical, and lab-on-chip sensors within the MEMS framework. - Impart knowledge of signal conditioning, data conversion, and interfacing techniques for MEMS devices with microcontrollers and IoT systems.			
Course Contents Unit I: Introduction to Sensors and Actuators: Classification and Performance Parameters, Integration with MEMS Devices			

Unit II: Mechanical and Thermal Sensors and Actuators: Pressure Sensors, Accelerometers, Gyroscopes, Thermal Sensors and Microheaters, Design and Simulation Unit III: Optical and Magnetic Sensors: Photonic Sensors and Optical MEMS, Magnetic Sensors and Magnetometers, Case Studies and Applications Unit IV: Chemical and Biomedical Sensors: Gas and Chemical Sensors, Biosensors and BioMEMS, Lab-on-Chip Technologies Unit V: Signal Conditioning and Interfacing: Signal Amplification and Filtering, Analog to Digital Conversion Techniques, Interfacing with Microcontrollers and IoT Systems.
Course Outcomes
On completion of this course, the students will be able to: CO1: Understand the fundamentals of sensors and actuators CO2: Learn different types of Mechanical and thermal sensors and actuators CO3: Knowledge of Optical and magnetic sensors CO4: Understand the working of chemical and biomedical sensors. CO5: Learn different techniques to interface sensors and actuators' signals to circuits and microcontrollers
Text Books/Reference Books
1. "Sensors and Actuators: Engineering System Instrumentation" by Clarence de Silva 2. "Micro and Smart Systems" Ananthasuresh et. Al. 3. "MEMS Sensors and Actuators" by M. Elwenspoek and R. Wiegerink 4. The MEMS Handbook, MEMS introduction and Fundamentals, Mohammed Gad el Hak 5. The MEMS Handbook, MEMS Design and Fabrication, Mohammed Gad el Hak 6. The MEMS Handbook, MEMS Applications, Mohammed Gad el Hak 7. Foundations of MEMS, Chang Liu 8. Handbook of Silicon based MEMS Materials and Technologies, Veikko Lindroos, Markku Tilli, Ahri Lehto, Teruaki Motooka

Course Code	Course Name	L – T – P	Credits
EE661	Microfabrication Techniques and Processes	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamentals of microfabrication and nanofabrication, including cleanroom protocols and silicon wafer processing. • Develop an understanding of lithography, pattern transfer, and thin film deposition techniques used in micro- and nano-scale device fabrication. • Enable students to analyze and apply various etching techniques, including both wet and dry etching, with focus on precision and selectivity. • Explore emerging microfabrication techniques and their applications in MEMS, NEMS, and microfluidic systems.			
Course Contents Unit I: Fundamentals of Microfabrication: Introduction to Microfabrication and Nanofabrication, Clean Room Standards and Protocols, Silicon Wafer Processing			

Unit II: Photolithography and Patterning: Optical Lithography and Mask Making, Advanced Lithography Techniques, Photoresists and Pattern Transfer	
Unit III: Thin Film Deposition: Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), Atomic Layer Deposition (ALD)	
Unit IV: Etching Techniques: Wet and Dry Etching Processes, Deep Reactive Ion Etching (DRIE), Selectivity and Anisotropy in Etching	
Unit V: Emerging Techniques and Applications: Nanoimprint and Soft Lithography, Microfluidic Device Fabrication, Applications in MEMS and NEMS	
Course Outcomes	
On completion of this course, the students will be able to:	
CO1: Understand the fundamentals of Microfabrication	
CO2: Learn the different steps involved in Photolithography and Patterning	
CO3: Knowledge of Thin Film deposition, CVD, etc.	
CO4: Study Etching Techniques	
CO5: Acquire knowledge of Nanoimprint and Soft Lithography, Microfluidic Device Fabrication, Applications in MEMS and NEMS	
Text Books/Reference Books	
1. "Fundamentals of Microfabrication" by Marc Madou 2. "Introduction to Microelectronic Fabrication" by Richard C. Jaeger 3. "Microsystem Technology" by Wolfgang Menz 4. The MEMS Handbook, MEMS introduction and Fundamentals, Mohammed Gad el Hak 5. The MEMS Handbook, MEMS Design and Fabrication, Mohammed Gad el Hak 6. The MEMS Handbook, MEMS Applications, Mohammed Gad el Hak 7. Foundations of MEMS, Chang Liu	

Course Code	Course Name	L – T – P	Credits
EE662	RF MEMS	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Introduce the fundamentals of RF MEMS, their applications, and distinctions from traditional solid-state RF components. - Develop understanding of mechanical and electromagnetic modeling techniques used in the design and analysis of RF MEMS devices. - Familiarize students with MEMS fabrication processes and the design of key RF MEMS components such as switches, varactors, and inductors. - Explore advanced RF MEMS systems, including phase shifters, filters, antennas, and address key research issues like reliability, packaging, and emerging architectures.			

Course Contents

Unit I: Introduction to RF MEMS

Introduction to RF MEMS, RF MEMS vs. solid state components, Application areas and case studies, RF MEMS development around the world

Review of basic mechanics and elements of strength of materials, Stress and strain, Stresses of beams, Deflection of beams, and spring constants

Unit II: Mechanical modeling of MEMS switches Static analysis Dynamic analysis

Review of Electromagnetic analysis and modeling, Transmission lines & high-frequency effects, scattering parameters, Review of numerical techniques

Electromagnetic modeling of RF MEMS switches: distributed models, lumped-element models

Unit III: Review of MEMS fabrication, Bulk micromachining, surface micromachining

Case studies of RF MEMS switches

RF MEMS inductors

FR MEMS varactors.

Unit IV: Switching networks series and shunt configurations, capacitive vs. ohmic contact absorptive switches

RF MEMS Phase Shifters

RF MEMS filters

RF MEMS antennas.

Unit V: Research issues Reliability Packaging Novel system architectures.

Course Outcomes

On completion of this course, the students will be able to:

CO1: Understand the fundamentals of modeling, design, technology, and applications of RF Micro-Electro-Mechanical Systems (MEMS).

CO2: Develop a strong understanding of how RF MEMS technology benefits the fields of intelligent communication systems, radars, and sensors.

CO3: Know about linear and non-linear electromechanical models for RF MEMS devices through analytical and numerical techniques.

CO4: Understand the high potential of RF MEMS in building a variety of reconfigurable high-frequency components and systems.

CO5: Learn different research topics, including reliability, packaging, and novel architectures.

Text Books/Reference Books

1. RF MEMS - Theory, Design and Technology, 1st Edition, Gabriel M. Rebeiz , John Wiley & Sons , 2003 , ISBN No. 047120169
2. Schaum's Outline of Statics and Strength of Materials, 1st Edition, John J. Jackson, Harold G. Wirtz , McGraw-Hill , 1983 , ISBN No. 0070321213
3. Microsensors MEMS and Smart Devices, 1st Edition, Julian W. Gardner, Vijay K. Varadan, Osama O. Awadelkarim , John Wiley & Sons , 2001 , ISBN No. 047186109X.\
4. Microsystem Design, 1st Edition, Stephen D. Senturia , Kluwer Academic Publishers, 2000, ISBN No. 0792372468
5. RF MEMS & Their Applications, 1st Edition, Vijay K. Varadan, K.J. Vinoy, K.A. Jose, John Wiley & Sons, 2003, ISBN No. 047084308X

Course Code	Course Name	L – T – P	Credits
EE663	MEMS Packaging	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamentals of miniaturization, levels of packaging, and their role in MEMS and microelectronics integration. • Develop understanding of key packaging processes, including interface challenges, dicing, bonding, sealing, and material selection. • Enable students to explore advanced packaging techniques such as vacuum, RF, optical, and 3D packaging, along with application-specific solutions. • Impart knowledge on environmental protection, reliability analysis, safety standards, and emerging research trends in MEMS packaging.			
Course Contents Unit I: Overview of Miniaturization, MEMS and Microelectronics-3levels of Packaging. Unit II: Critical Issues viz., Interface, Testing & evaluation. Packaging Technologies like Wafer dicing, Bonding and Sealing. Unit III: Design aspects and Process Flow, Materials for Packaging, Top-down System Approach. Different types of Sealing Technologies like brazing, Electron Beam welding and Laser welding. Unit IV: Vacuum Packaging with Moisture Control. 3D Packaging examples. Bio Chips/Lab-on-a-chip and micro fluidics, Various RF Packaging, Optical Packaging, Packaging for Aerospace applications. Advanced and Special Packaging techniques–Monolithic, Hybrid etc., Transduction and Special packaging requirements for Absolute, Gauge and differential Pressure measurements, Temperature measurements, Accelerometer and Gyro packaging techniques, Unit V: Environmental Protection and safety aspects in MEMS Packaging. Reliability Analysis and FMECA. Media Compatibility Case Studies, Challenges/ Opportunities/ Research frontier.			
Course Outcomes On completion of this course, the students will be able to: CO1: Understand the fundamentals of Miniaturisation, MEMS, and Microelectronics. CO2: Understand the critical issues in miniaturization and packaging. CO3: Learn Design aspects and Process Flow, Different types of Sealing Technologies CO4: Understand different packaging techniques. CO5: Learn about environmental Protection and safety aspects in MEMS Packaging.			
Text Books/Reference Books 1. "MEMS Packaging" by Tai-Ran Hsu 2. "MEMS / MOEMS packagibg" by Ken Gilleo doi.contentdirections.com 3. "Johan Liu, James E. Morris, Per-Erik Tegehall, Cristina Andersson, Jussi Sarkka, Olli Salmela 4. RF MEMS - Theory, Design and Technology, 1st Edition, Gabriel M. Rebeiz, John Wiley & Sons, 2003, ISBN No. 0471201693 5. Schaum's Outline of Statics and Strength of Materials, 1st Edition, John J. Jackson, Harold G. Wirtz, McGraw-Hill, 1983, ISBN No. 0070321213 6. Microsensors, MEMS and Smart Devices, 1st Edition, Julian W. Gardner, Vijay K. Varadan, Osama O. Awadelkarim, John Wiley & Sons, 2001, ISBN No. 047186109X 7. Microsystem Design, 1st Edition , Stephen D. Senturia , Kluwer Academic Publishers , 2000 , ISBN No. 0792372468 8. RF MEMS & Their Applications, 1st Edition, Vijay K. Varadan, K.J. Vinoy, K.A. Jose, John Wiley & Sons, 2003, ISBN No. 047084308X			

Course Code	Course Name	L – T – P	Credits
EE664	MEMS Packaging and Reliability	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamental requirements, types, and challenges of MEMS packaging at wafer, chip, and system levels. • Develop an understanding of materials, bonding methods, and sealing techniques used in MEMS packaging. • Enable students to analyze interconnection technologies and assembly methods, including 3D integration and packaging for specialized MEMS devices. • Impart knowledge of reliability testing, failure mechanisms, and advanced packaging trends through real-world MEMS case studies.			
Course Contents Unit I: Introduction to MEMS Packaging, Overview of MEMS Packaging Requirements, Types of Packaging: Wafer-level, Chip-scale, and System-level Unit II: Packaging Materials and Techniques, Packaging Materials: Polymers, Metals, Ceramics, Adhesive Bonding, Anodic Bonding, and Glass Frit Bonding, Hermetic and Non-Hermetic Sealing Techniques Unit III: Interconnection and Assembly, Electrical Interconnection Techniques: Wire Bonding, Flip-Chip Bonding, 3D Integration and Through-Silicon Vias (TSV), Packaging for RF MEMS and Optical MEMS Unit IV: Reliability and Testing, Mechanical Reliability: Shock and Vibration Testing, Thermal Cycling and Humidity Testing, Failure Analysis and Quality Assurance Unit V: Emerging Trends and Case Studies, Advanced Packaging for IoT and Wearable MEMS, Packaging for Biomedical MEMS, Case Studies: Automotive Sensors, Inertial Measurement Units			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Understand the fundamentals of Miniaturisation, MEMS, and Microelectronics. CO2: Understand the critical issues in miniaturization and packaging. CO3: Learn Design aspects and Process Flow, Different types of Sealing Technologies CO4: Understand different packaging techniques. CO5: Learn about environmental Protection and safety aspects in MEMS Packaging.			
Text Books/Reference Books			
1."MEMS Packaging" by Tai-Ran Hsu 2."MEMS / MOEMS packaging" by Ken Gilleo doi.contentdirections.com 3." Johan Liu, James E. Morris, Per-Erik Tegehall, Cristina Andersson, Jussi Sarkka, Olli Salmela 4. RF MEMS - Theory, Design and Technology, 1st Edition, Gabriel M. Rebeiz, John Wiley & Sons, 2003, ISBN No. 0471201693 5. Schaum's Outline of Statics and Strength of Materials, 1st Edition, John J. Jackson, Harold G. Wirtz, McGraw-Hill, 1983, ISBN No. 0070321213 6. Microsensors, MEMS and Smart Devices, 1st Edition, Julian W. Gardner, Vijay K. Varadan, Osama O. Awadelkarim, John Wiley & Sons, 2001, ISBN No. 047186109X 7. Microsystem Design, 1st Edition, Stephen D. Senturia, Kluwer Academic Publishers, 2000, ISBN No. 0792372468 8. RF MEMS & Their Applications, 1st Edition, Vijay K. Varadan, K.J. Vinoy, K.A. Jose, John Wiley & Sons, 2003, ISBN No. 047084308X			

Course Code	Course Name	L – T – P	Credits
EE665	Low-Power Digital IC Design	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamentals of low-power VLSI design, its importance, and applications in modern digital systems. • Develop an understanding of low-voltage device modeling and design methodologies using CMOS and BiCMOS technologies. • Enable students to analyze and design low-power digital subsystems and architectures such as adders, multipliers, and PLLs. • Impart knowledge of power estimation techniques and power reduction strategies at physical, circuit, architectural, and algorithmic levels.			
Course Contents Unit I: Low-Power VLSI Design: An Overview & Technology Low-Power Applications, Low-Power Design Methodology, Power Reduction Through Process Technology, Low-Voltage Process Technology, LOW-VOLTAGE PROCESS TECHNOLOGY, CMOS Process Technology, 2.5 BiCMOS Technology 36 Unit II: Low-Voltage Device Modeling: MOSFET structure and operation, spice models of the MOS transistor, CMOS power supply voltage scaling, low-voltage low-power VLSI CMOS, circuit design. Unit III: Low-Voltage VLSI BiCMOS Circuit Design Conventional BiCMOS Logic, Low-Voltage BiCMOS Families, Low-Voltage BiCMOS Applications Unit IV: VLSI CMOS Subsystem Design Parallel Adders, Parallel Multipliers, Data Path, Regular Structures, PLL Unit V: Low-Power VLSI Design Methodology: LP Physical Design, LP Gate-Level Design, LP Architecture-Level Design, Algorithmic-Level Power Reduction, Power Estimation Techniques, Low-power neuromorphic computing systems, Emerging Devices: Architectural Approaches, System-Level Examples:			
Course Outcomes On completion of this course, the students will be able to: CO1: Understand the fundamentals of low-power VLSI CO2: Choose the appropriate low-power device modeling CO3: Acquire knowledge of Low-Voltage VLSI BiCMOS Circuit Design CO4: Understand Low-Power VLSI CMOS Subsystem Design CO5: Learn Low-Power VLSI Design Methodology & neuromorphic computing			
Text Books/Reference Books 1. Low-Power Digital Vlsi Design Circuits and Systems, A. Bellaouar, M Elmasry 2. CMOS Analog Circuit Design by P.E. Allen & D.R. Holberg 3. Design of Analog CMOS Integrated Circuits by Behzad Razavi 4. Analysis and Design of Analog Integrated Circuits by P.R. Gray, P.J. Hurst, S.H. Lewis, R.G. Meyer. 5. Low Power Design Methodologies by J. Rabaey 6. Low-Power CMOS Circuits: Technology, Logic Design, and CAD Tools by C. Piguet 7. Phase-Locking in High-Performance Systems – B. Razavi.			

Course Code	Course Name	L – T – P	Credits
EE666	Optical Space Communication	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Impart knowledge about Optical Space Communication. • Introduce different Modulation Techniques • Impart the knowledge of Channel Modelling • Provide knowledge of AI integration with OSA.			
Course Contents Unit I: Introduction to optical space communication: Calculating the power budget of a space communication link, considering losses and gains. Satellite communication, deep space probes, and high-speed data transfer between ground stations and space. Principles and applications of transmitting data using lasers and other optical devices in space. Fundamentals of optical communication, space link technology, and address specific challenges like atmospheric turbulence and signal processing techniques. Unit II: Advanced modulation techniques: Design of both ground-based and space-based optical transmitters and receivers. Coherent detection techniques and their advantages in long-distance communication. Quantum communication, optical orbital angular momentum, and free-space optical networking. Unit III: Channel modelling and link budget calculations: Techniques like equalization, adaptive filtering, and advanced modulation formats to enhance communication quality. Unit IV: Channel turbulence effects measurement and mitigation: Optical transceivers, atmospheric effects on propagation, and pointing, acquisition, and tracking (PAT) systems. Addressing issues such as atmospheric turbulence, noise, and signal degradation in space communication. Unit V: AI for optical space communications: AI-based adaptive optics techniques: reference wave in an adaptive optics system, wavefront sensors (quadrature sensors, phase difference sensors, Hartmann sensor), wavefront correctors (modal correctors, deformable mirrors, segmented correctors), modal phase correction, modal phase conjugation.			
Course Outcomes			
CO1: Acquire knowledge of optical space communication CO2: Understand the modulation/demodulation schemes for high-data-rate space communications CO3: Understand the atmospheric channel modelling and link budget calculations CO4: Learn about the channel effects and mitigation techniques CO5: Understand the AI requirements for space optical communications			

Text Books/Reference Books	
1. B. Djordjevic, Advanced Optical and Wireless Communications Systems. Springer International Publishing AG, 2018. 2. N. Zhao, X. Li, G. Li and J. M. Kahn "Capacity Limits of Spatially Multiplexed Free-Space Communication", Nature Photon., vol. 9, pp. 822-826, December 2015. 3. J. Wang, J. M. Kahn and K. Y. Lau "Minimization of Acquisition Time in Short-Range Free-Space Optical Communication", Applied Optics, vol. 41, no. 12, pp. 7592-7602, December 2002. 4. C. Andrews, R. L. Philips, Laser Beam Propagation through Random Media, 2nd Ed. SPIE Press, Bellingham, Washington, USA, 2005. 5. I. B. Djordjevic, Advanced Optical and Wireless Communications Systems, Springer, Dec. 2017/Jan. 2018. 6. Shlomi Arnon, Robert Schober, George Karagiannidis, John Barry, Murat Uysal, Advanced Optical Wireless Communication Systems, Cambridge University Press, 2012	

Course Code	Course Name	L – T – P	Credits
EE667	Mobile and Satellite Communication	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Understand the fundamentals of wireless communication systems, including channel modeling, modulation techniques, diversity, and performance metrics.
- Analyze cellular communication systems covering capacity, frequency reuse, multiple access methods, equalization, diversity, and modern technologies like GSM, CDMA, OFDM, 4G, and 5G.
- Study mobile radio propagation mechanisms and models, including reflection, diffraction, scattering, fading, and their impact on communication systems.
- Gain knowledge of satellite communication principles, including orbital mechanics, space segment, earth segment, link budget, and environmental effects.
- Explore satellite access techniques and services such as FDMA, TDMA, CDMA, DBS, VSAT, GPS, and their applications in modern communication systems.

Course Contents

Prerequisite: Introduction to Wireless Communication, Motivation, Types of Wireless Communication, Wireless Channel Modeling, Random Variable, Fading Channels, Linear Transformation, Bit Error Rate (BER) and Symbol Error rate (SER), BER and SER performance for Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), M-ary Pulse Amplitude Modulation (PAM) and M-ary PSK in Additive White Gaussian Noise (AWGN), Diversity Techniques, Maximum Delay Spread, RMS Delay Spread, RMS delay based on power profile, Average Delay Spread in Outdoor Cellular Channels, Coherence Bandwidth in Wireless Communications, Inter symbol Interference (ISI), Doppler Fading.

Unit I: Cellular Communications: Introduction to Cellular Communications, Cell Capacity and Frequency reuse, Coverage Improvement, Multiple Access Technologies, Cellular Processes Call Setup, Handover, Teletraffic Theory, Equalization and Diversity Techniques, Modulation and Coding Techniques for Mobile Communication, GSM, CDMA, 4G, VOLTE and 5 G technologies, Introduction to Wireless OFDM – OFDM principles, system model –

Generation of sub carrier using IFFT, windowing, choice of OFDM parameters, OFDM signal processing. Unit II: Mobile Radio Propagation: Introduction to Mobile Radio Propagation, Reflection, Diffraction, Scattering, Propagation Models, Doppler Effect, Delay Spread, Ultra-Wideband Communication System, Fading, TDM, FDM, TDMA, FDMA, CDMA, OFDM. Unit III: Overview of Satellite Systems: Frequency Allocations for Satellite Services, Kepler's Law, Orbital Elements, Apogee and Perigee, Orbital Perturbations, Effects of a Non-spherical Earth, Atmospheric Drag, Inclined Orbits, Sidereal Time, Equatorial Coordinate System, Predicting Satellite Position. Unit IV: Space Segment & Earth Segment: Introduction, Antenna look angles, Limits of visibility, Near-geostationary orbits, Earth eclipse of satellite, Sun transit outage, Power supply, Attitude control, spinning satellite stabilization, Station keeping, Transponders, Antenna subsystem, Carrier-to-Noise ratio for uplink and downlink, System noise, Effects of rain, Rain-fade margin. Unit V: Satellite Access & DBS Services: Preassigned FDMA, Demand-Assigned FDMA, FDMA downlink analysis, Companion of uplink power requirements for FDMA & TDMA. On-board signal processing for TDMA/FDMA operation, Satellite switched TDMA, CDMA, Orbital Spacings, Power Rating and Number of Transponders, Frequencies and Polarization, Transponder Capacity, Bit Rates for Digital Television, MPEG Compression Standards, Forward Error Correction, Home Receiver Outdoor Unit (ODU), Home Receiver Indoor Unit (IDU), Downlink Analysis, Uplink, Problems, Satellite Mobile Services, VSATs, Radarsat, Global Positioning Satellite System.
Course Outcomes On completion of this course, the students will be able to: CO1: Understand the basics of wireless communication, basic terms such as Bit error rate, symbol error rate, etc., and the advantages and disadvantages of different wireless communication techniques. CO2: Learn cellular communications basics and mobile radio propagation. CO3: Understand the basics of Satellite Systems, learning about orbital systems and sub-systems. CO4: Know about the Earth & Space segment, applications of direct satellite broadcasting, like GPS, and other mobile services. CO5: Know about the Uplink & Downlink Analysis, Satellite Mobile Services.
Text Books 1. Fundamentals of Wireless Communications – David Tse and Pramod Viswanath, Publisher Cambridge University Press. 2. Wireless Communications: Andrea Goldsmith, Cambridge University Press. 3. Satellite Communications, Dennis Roddy, McGraw-Hill Publication Third edition 2001. 4. Satellite Communications – Timothy Pratt, Charles Bostian and Jeremy Allnutt, WSE, Wiley Publications, 2nd Edition, 2003.
Reference Books 1. Wireless Communications – Andreas Molisch – Wiley IEEE Press. 2. Mobile Wireless Communications – Mischa Schwartz – Cambridge University Press. 3. Wilbur L. Pritchards Henri G. SuyderHond Robert A. Nelson, Satellite Communication Systems Engineering, Pearson Education Ltd., Second edition 2003.

4. Satellite Communications: Design Principles – M. Richharia, BS Publications, 2nd Edition, 2003.

Course Code	Course Name	L – T – P	Credits
EE668	Machine Learning for Signal Processing	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the fundamentals of machine learning, including problem formulation, system design, and different learning paradigms. • Learn supervised learning algorithms for regression and classification, including decision trees, neural networks, SVMs, and regularization techniques. • Explore unsupervised learning methods such as clustering, Gaussian mixture models, and dimensionality-based approaches. • Analyze model evaluation and selection techniques. • Develop practical skills in Python for implementing regression, classification, and clustering algorithms.			
Course Contents Unit I: Well-posed learning problems, Designing a learning system, Perspectives and issues in machine learning. Types of Machine Learning-Supervised, Unsupervised, Reinforcement learning. Unit II: Supervised Learning Algorithms- Regression and Classification- Linear, Polynomial Regularization, Regression based on Normal Equations, Instance-based learning- Decision Trees, Artificial Neural Networks, Support Vector Machines, Support Vector Regression. Unit III: Unsupervised learning- k-means, Gaussian Mixture Models, Expectation Maximization, Hierarchical clustering, Spectral clustering. Unit IV: Bias variance trade-off, VC dimension, Model selection, AUC-ROC, Metrics-Regression, Classification, Clustering, K-Fold cross-validation. Unit V: Python Implementation of Regression, Classification, and Clustering Algorithms.			
Course Outcomes			
On completion of this course, the students will be able to: CO1: Learn the basic principles of designing a learning system and the types of machine learning. CO2: Learn the concepts of Supervised Learning Algorithms with Regression and Classification. CO3: Learn the basics of Unsupervised learning, including k-means, Gaussian Mixture Models, Expectation Maximization, Hierarchical clustering, and Spectral clustering. CO4: Apply knowledge and skills to understand the bias-variance trade-off, VC dimension, Model selection, AUC-ROC, Metrics-Regression, and Clustering. CO5: Acquire the knowledge of the Implementation of Regression, Classification, and Clustering Algorithms.			
Text Books			
1. E. Alpaydin, Introduction to Machine Learning, 3rd Edition, Prentice Hall (India) 2015. 2. R. O. Duda, P. E. Hart and D. G. Stork, Pattern Classification, 2nd Edn., Wiley India, 2007. 3. C. M. Bishop, Pattern Recognition and Machine Learning (Information Science and Statistics), Springer, 2006.			

4. S. O. Haykin, Neural Networks and Learning Machines, 3rd Edition, Pearson Education (India), 2016.
Reference Books
1. Tom M. Mitchell, Machine Learning, Indian Ed., 2017, Tata McGraw Hill Education.
2. Stephen Marsland, Machine Learning: An Algorithmic Perspective, 2nd Ed., 2014, Taylor & Francis (CRC).
3. Kevin Murphy, Machine Learning, A probabilistic perspective, 2012, MIT Press.
4. O'Reilly, Hands on Machine Learning with Scikit-Learn, Keras & TensorFlow, 3rd Edition, 2022

Course Code	Course Name	L – T – P	Credits
EE669	Deep Learning and Applications	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand the fundamentals of neural network models. - Apply dimensionality reduction and representation learning techniques. - Implement regularization methods to improve generalization in deep learning models, including dropout, early stopping, and ensemble approaches. - Explore advanced deep learning architectures. - Develop practical skills for building and optimizing deep learning models using modern initialization, normalization, and training strategies.			
Course Contents Unit I: McCulloch Pitts Neuron, Thresholding Logic, Perceptrons, Perceptron Learning Algorithm. Multilayer Perceptrons (MLPs), Representation Power of MLPs, Sigmoid Neurons, Gradient Descent, Feedforward Neural Networks, Representation Power of Feedforward Neural Networks. Unit II: Feed-Forward Neural Networks, Backpropagation, Gradient Descent (GD), Momentum Based GD, Nesterov Accelerated GD, Stochastic GD, AdaGrad, RMSProp, Adam, Eigenvalues and eigenvectors, Eigenvalue Decomposition, Basis. Unit III: Principal Component Analysis and its interpretations, Singular Value Decomposition, Autoencoders and relation to PCA, Regularization in autoencoders, Denoising autoencoders, Sparse autoencoders, Contractive autoencoders. Unit IV: Regularization: Bias Variance Tradeoff, L2 regularization, Early stopping, Dataset augmentation, Parameter sharing and tying, Injecting noise at input, Ensemble methods, Dropout. Unit V: Greedy Layerwise Pre-training, Better activation functions, Better weight initialization methods, Batch Normalization, Learning Vectorial Representations Of Words. Convolutional Neural Networks, AlexNet, VGGNet, ResNet, Visualizing Convolutional Neural Networks, Guided Backpropagation. Recurrent Neural Networks, Backpropagation through time (BPTT), Vanishing and Exploding Gradients, GRU, LSTM.			
Course Outcomes			

On completion of this course, the students will be able to: CO1: Learn the basics of the principles of spatial signals: Array processing fundamentals, signals in space and time. CO2: Get the concepts of sensor arrays and Uniform linear arrays. CO3: Learn the basics of beamforming-related concepts. CO4: Apply knowledge and skills to understand the direction of arrival methods. CO5: Acquire knowledge of compressed sensing and sparse signal processing.
Text Books/Reference Books
1.Deep Learning, An MIT Press book, Ian Goodfellow and Yoshua Bengio and Aaron Courville. 2.Deep Learning- Ian Goodfellow, Yoshua Benjio, Aaron Courville, The MIT Press 3.Pattern Classification- Richard O. Duda, Peter E. Hart, David G. Stork, John Wiley & Sons Inc.

Course Code	Course Name	L – T – P	Credits
EE670	Time Frequency Analysis	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand the fundamentals of Fourier and spectral analysis. - Analyze complex, analytic, and multicomponent signals using duration–bandwidth principles and density functions. - Apply the Uncertainty Principle and explore time–frequency invariance properties for signal analysis. - Learn and implement time–frequency transforms. - Explore quadratic time–frequency methods.			
Course Contents Unit I: Basics of Fourier Analysis, Spectral Theory, Fundamentals of Time-frequency Analysis, Instantaneous Frequency and Instantaneous Bandwidth, Basic Concepts & Definition of Bandwidth Equation, AM-FM Contribution to the bandwidth, non-additivity of spectral property. Unit II: Complex signal, Analytic Signal and its physical interpretation, Multicomponent Signals, Duration-Bandwidth Principle, Density function, One-dimensional density and its characteristic functions, two-dimensional densities, Joint Density. Unit III: Uncertainty Principle, Proof of Uncertainty Principle, Local average, global average, time & frequency shift invariance. Unit IV: Gabor Transform, The Short-Time Fourier Transform/Spectrogram, Time-Frequency Localization, Continuous Wavelet Transform/ Scalogram, Multiresolution Analysis. Unit V: Quadratic Time-Frequency Transform, Wigner-Ville Distribution, Signal Processing Applications, Image Processing Applications.			
Course Outcomes			

On completion of this course, the students will be able to:
CO1: Learn the fundamentals of Fourier Analysis, Spectral Theory, and Time-frequency.
CO2: Acquire knowledge of various concepts such as Complex signal, Analytic Signal, Multicomponent Signals, Duration-Bandwidth, and Density function.
CO3: Learn the basics of the uncertainty principle, Local and global average, time & frequency shift invariance.
CO4: Apply knowledge and skills to understand the Gabor Transform, STFT, Spectrogram, TF Localization, and Wavelet Transform.
CO5: Acquire the knowledge of Quadratic Time-Frequency and Wigner-Ville Distribution.
Text Books/Reference Books
1. L. Cohen, Time-Frequency Analysis, Prentice Hall, 1995, ISBN:0135945321.
2. S. Mallat, A Wavelet Tour of Signal Processing (2nd edition), Academic Press, 2008, ISBN: 012466606X
3. B. Boashash, Time-Frequency Signal Analysis and Processing: A Comprehensive Reference, Elsevier Science, 2003, ISBN-13: 978-0080443355.4.
4. R. M. Rao and A. S. Bopardikar, Wavelet Transforms: Introduction to Theory & Applications, Prentice Hall, 1998, ISBN-13: 978-0201634631

Course Code	Course Name	L – T – P	Credits
EE671	Convex Optimization for Signal Processing	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand the fundamentals of convex sets and convex functions. - Formulate and analyze convex optimization problems. - Develop skills in approximation and fitting techniques such as norm approximation, regularization, and robust fitting. - Implement unconstrained optimization methods, including gradient descent, Newton's method, and steepest descent, for solving practical problems.			
Course Contents Unit I: Affine and Convex Sets, Operations that preserve convexity, Separating and supporting Hyperplanes, Convex Functions, Conjugate function, Quasi-convex function, Log-concave and log-convex function, Convexity with respect to generalized inequalities Unit II: Convex optimization problems, Optimization problems, convex optimization, Linear optimization problems, Quadratic optimization problems, Geometric programming, generalized inequality constraints, Vector optimization. Unit III: Duality, The Lagrange dual function, The Lagrange dual problem, Geometric interpretation, Saddle-point interpretation, Optimality conditions, Perturbation and sensitivity analysis, Generalized inequalities. Unit IV: Approximation and fitting, Norm approximation, Least-norm problems, Regularized approximation, Robust approximation, Function fitting and interpolation. Unit V: Unconstrained minimization problems, Descent methods, Gradient descent method, Steepest descent method, Newton's method, Self-concordance.			
Course Outcomes			

On completion of this course, the students will be able to: CO1: Learn the fundamentals of Affine and Convex Sets, Operations that preserve convexity, Separating and supporting Hyperplanes. CO2: Learn the concepts of Optimization problems, convex optimization, Linear optimization problems, Quadratic optimization problems. CO3: Learn the basics of Duality, the Lagrange dual function, Geometric interpretation, Saddle-point interpretation, Optimality conditions. CO4: Apply knowledge and skills to understand the approximation and fitting, Norm approximation, Least-norm problems, regularized approximation, and Robust approximation. CO5: Acquire the knowledge of Unconstrained minimization problems, Descent methods, the Gradient descent method, and the Steepest descent method.
Text Books/Reference Books
1. Optimization Models by G.C. Calafiore and L. El Ghaoui, Cambridge University Press, 2014. Link: https://people.eecs.berkeley.edu/~elghaoui/optmodbook.html 2. Convex Optimization by Stephen Boyd and L. Vandenberghe, Cambridge University Press. Available online at: https://web.stanford.edu/~boyd/cvxbook/ 3. Algorithms for Convex Optimization by Nisheeth K. Vishnoi, Cambridge University Press. Available online at: https://convex-optimization.github.io 4. Optimization III: Convex and Nonlinear Programming by Ben-Tal and Nemirovski. Lecture Notes.

Course Code	Course Name	L – T – P	Credits
EE672	Time Series Analysis and Forecasting	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand the fundamentals of time series analysis. • Apply exponential smoothing techniques. • Model stationary and nonstationary processes using AR, MA, ARMA, ARIMA, and related forecasting methods. • Perform spectral analysis and advanced forecasting.			
Course Contents Unit I: Introduction to Time Series Analysis: Review of Time Series Analysis. Growth models: Modified Exponential Curve, Gompertz curve, Logistic curve and their Fitting; Measurement of cyclical component: Harmonic analysis, auto regression series: Markoff and Yule's series, Periodogram and correlogram analysis, measurement of irregular component: variate difference method. Difference Equations, Lag Operators, pth-Order Difference Equations. White Noise, Expectations, Stationarity, and Ergodicity. Models of Nonstationary Time Series: Why Linear Time Trends and Unit Roots? Random Walk Models, Brownian Motion, Geometric Brownian Motion. Canonical Correlation Time Series Models of Heteroscedasticity: ARCH and GARCH model, Granger Causality Test ADF, KPSS Test for Stationary.			

Unit II: Exponential Smoothing Methods: Trend adjusted exponential smoothing, double and triple exponential smoothing, Holt and Winters smoothing, Chow's adaptive control methods, brown's one parameter adaptive method: Unit III: Detailed Study of the Stationary Processes: Linear Models, Autoregressive Processes, Moving Average (MA), Auto Regressive (AR), ARMA and AR Integrated MA(ARIMA)models - forecasting with ARIMA models. Unit IV: Box-Jenkins models: Discussion (without proof) of estimation of mean, auto covariance and auto-correlation functions under large sample theory. Choice of AR and MA periods. Estimation of ARIMA model parameters. Unit V: Spectral Analysis and Forecasting: Spectral analysis of a weakly stationary process. Periodogram and correlogram analyses. Computations based on the Fourier transform, principles of Forecasting, Forecasts with Gaussian Processes, Wold's Decomposition, and the Box-Jenkins Modelling Philosophy, Parameter Estimation, and Maximum Likelihood Estimation. Vector Auto regressions; Bivariate Granger Causality Tests. Understanding Kalman Filter.	
Course Outcomes	
On completion of this course, the students will be able to: CO1: Learn about Exponential, Gompertz, and Logistic curves and their fitting. CO2: Understand trend-adjusted exponential smoothing methods. CO3: Study MA, AR, ARMA, and ARIMA models. CO4: Understand Box-Jenkins models and estimate auto-covariance and auto-correlation functions. CO5: Study Periodogram and Correlogram analyses.	
Text Books/Reference Books	
1. Time Series Analysis by James D. Hamilton, Princeton University Press, 2012. 2. Time Series Analysis and Its Applications: With R Examples by Robert H. Shumway, David S. Stoffer, Springer Texts in Statistics, 2017. 3. Understanding the Kalman Filter by Richard J. Meinhold, Nozer D. Singpurwalla, The American Statistician Vol. 37, No. 2, pp. 123-127, (May, 1983). 4. The Statistical Analysis of Time Series by Anderson, T.W., Wiley, 1971. 5. Forecasting and Time Series Analysis by Montgomery, D.C. and Johnson, L.A., McGraw Hill, 1977.	

Course Code	Course Name	L – T – P	Credits
EE673	Real-Time Operating Systems	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamentals of operating systems with emphasis on real-time concepts, system structures, process management, and inter-process communication. • Develop an understanding of process synchronization, memory management, and methods for handling deadlocks in real-time environments. • Enable students to analyze and implement real-time scheduling algorithms for uniprocessor and multiprocessor systems, including fault-tolerant approaches. • Impart knowledge of RTOS standards, architectures, and applications through case studies, with practical exposure to Linux and TinyOS programming.			

Course Contents

Unit I: Introduction to Real Time Operating System: Overview of Operating System, Fundamentals and keywords, structures, OS user view, system view, Interrupts, Storage structures, I/O structures, Single, Multi and clustered systems, Dual mode and multimode operation, Resource Management, Timers and I/O, virtualization and distributed systems, lists, stacks, Hash functions, computing environments, Building and Booting an operating system, operating system debugging, Queues, Trees.

Programming –Basics of Linux Operating System

Unit II: Process Management: Process Management, Process scheduling, Message queues, Mailboxes, Pipes, Inter-Process Communication (IPC), IPC in shared memory message passing systems, threads and concurrency, Multithreading models, implicit threading, threading issues, Kernel Structure Critical sections, tasks, task states, task scheduling, task control blocks, task management, time management, Device drivers.

Programming – System calls for Linux operating system and Shell programs

Unit III: Process Synchronization and Memory Management Synchronization tools, the critical section problem, Hardware support for synchronization, Mutex locks, Semaphores, semaphore usage and implementation, Monitors, implementation using semaphores, resuming processes within a monitor, Deadlocks, characterization, methods for handling, deadlock prevention, Deadlock avoidance, 'deadlock detection, Recovery from Deadlock, Memory management, main memory allocation, contiguous memory allocation, paging, structure of the page table, virtual memory, allocating kernel memory

Programming - Producer consumer problem using Semaphores, IPC using Shared Memory, Bankers Algorithm for Deadlock avoidance, Algorithm for deadlock detection, Memory allocation methods

Unit IV: Real Time Scheduling and Scheduling Algorithms: Uniprocessor scheduling, types of scheduling, pre-emptive and non-preemptive scheduling, dispatcher, scheduling algorithms-FCFS, Round robin scheduling, priority based scheduling, thread scheduling, multiprocessor scheduling, Real Time CPU scheduling, Rate monotonic scheduling, Earliest DeadlineFirst scheduling, POSIX Real-Time Scheduling, Fault tolerant scheduling, aperiodic scheduling, Schedulability problem: classification- schedulability test, Worst Case Execution Time (WCET), spring algorithm, Sporadic scheduling, Programming – CPU Scheduling Algorithms (Priority based scheduling, Round Robin Scheduling, First Come First Serve (FCFS) and shortest scheduling Algorithms)

Unit V: RTOS and Case Studies Introduction to POSIX, POSIX standards, Design of POSIX, RTOS-Tiny OS introduction, example application, Names and Program Structure, Basic Programming, component signatures, Interfaces, Component Implementation, Split phase interfaces, configurations, applications, Case Study-RTOS for Control Systems, Case Study-RTOS for Voice over IP Programming - File organization techniques, Tiny OS

Course Outcomes

On completion of this course, the students will be able to:

CO1: Understanding the fundamentals of an operating system.

CO2: Understanding and illustrating the process concepts and kernel structure

CO3: Learn and construct the process synchronization and memory management

CO4: Understand and analyze the design a scheduling algorithm.

CO5: Learn & apply the knowledge to use and design RTOS

Text Books/Reference Books

1. Abraham Silberschatz, Peter Baer Galvin, Greg Gagne, Operating System Concepts, Tenth edition, Wiley, 2018.
2. Jean J. Labrosse, The microC /OS-II The Real Time Kernel Optics, CMP Books, 2nd edition, 2011.
3. C.M. Krishna and G.Shin, Real Time Systems, McGraw-Hill International Edition, 2010(3rd Reprint) "MEMS Packaging" by Tai-Ran Hsu
4. Jim Cooling, "Real-Time Operating Systems Book 1: The Foundations", Lindtree Associates, 2018
5. Donald A. Lewine, POSIX Programmer's Guide, 1991. Philip Levis, David Gay, Tiny OS Programming Cambridge University Press 2009.

Course Code	Course Name	L – T – P	Credits
EESL01	Signal Processing Laboratory I	3-0-0	3
Course Outcomes:			
CO1	Understanding the basics of MATLAB and LabVIEW		
CO2	Understand Model-based power spectral estimation techniques		
CO3	Speech analysis using LPC		
CO4	Digital filter design using MATLAB & implementation in FPGA		
CO5	Design of Quadrature Mirror Filters (QMF)		
List of experiments:			
Sl. No	Experiment		
1.	Introduction of MATLAB/Simulink, LabVIEW, and their toolboxes		
2.	Sampling and Reconstruction of Signals		
3.	Deterministic & Random Signal analysis using power spectral estimation techniques 1. Periodogram power spectral estimation technique 2. PSD through the correlogram technique 3. Spectrogram analysis		
4.	Model-based power spectral estimation techniques 1. AR Model, MA Model, ARMA Model 2. Covariance methods		
5.	Speech analysis using LPC. Performance analysis with respect to the Prediction Filter Order & SNR		
6.	Digital filter design using MATLAB & implementation in FPGA a) FIR & IIR Filters		
7.	High-Resolution pseudo-spectral estimation technique via a) MUSIC & ESPRIT		
8.	Design of Quadrature Mirror Filters (QMF)		

Course Code	Course Name	L – T – P	Credits
EESL02	Signal Processing Laboratory II	3-0-0	3
Course Outcomes:			

CO1	Understanding the AM, FM, and PM waveforms
CO2	Design a FIR adaptive filter
CO3	Target Signal & Ambient Noise Simulation
CO4	Wavelet transform-based case study
CO5	Detection of targets using NP Criterion & target parameter
List of experiments:	
Sr. No.	Experiments
1.	Simulation of multi-component sinusoidal, AM, FM, AM-FM signals and their frequency spectrum, time-frequency representation visualization.
2.	Simulation of multi-component sinusoidal, AM, FM, AM-FM signals in a noisy environment (AWGN level 5dB, 0dB, 5dB, 10dB, 20dB) and their frequency spectrum, time-frequency representation visualization.
3.	Simulation of the analytic form of signal possesses (a) a mono-component signal, (b) a multicomponent signal.
4.	Design a FIR adaptive filter to remove different types of noises from a natural signal, such as physiological signals, EEG, ECG, and speech signals.
5.	Wavelet transform-based case study
6.	Introduction of MATLAB/Simulink, LabVIEW, and its toolboxes to simulate Signal models in the presence of various ambient Noise models (correlated/uncorrelated, White/Colored with Gaussian mixture models)
7.	Target Signal & Ambient Noise Simulation (Scalar & Vector Sensor Array Data Vector Simulation): Generation of Multiple spatially separated targets in the presence of Strong interferences and Additive Correlated/Uncorrelated, White/Colored Ambient Noise
8.	Development of Detection Techniques for the following cases 1. Constant amplitude Signal in AWGN 2. Time-varying Known Signals in AWGN 3. Unknown Signals in AWGN
9.	Development and performance comparison of the following Estimation techniques using a given signal & noise model (sensor data model) - MLE, MMSE, Bayes Estimator, MAP Estimator, Expectation Maximization (EM) algorithm
10.	Case Study: Detection of targets using NP Criterion & target parameter (Range, bearing, Doppler, etc.) estimation algorithms. Performance comparison of Conventional Energy Detectors and Coherent Matched Filter Techniques

Course Code	Course Name	L – T – P	Credits
EERL01	Radar Laboratory I	3-0-0	3

Course Outcomes:	
CO1	Understanding the basic FPGA Design Flow
CO2	Familiarization with FPGA Boards
CO3	Phased array radar design
CO4	RCS measurement
CO5	Characterization of radar subsystems/components
List of experiments:	
SL No	Experiments
1.	The Basic FPGA Design Flow 1. To understand the use of Xilinx ISE 2. To understand Xilinx Synthesis Technology or XST. 3. Familiarization with Xilinx Vivado Design Tools.
2.	Familiarization with FPGA Boards 1. Xilinx FPGA Boards (Virtex 6, Kintex7) 2. Implementation of a Full adder, ALU, Memory, and FIFO on an FPGA
3.	Fault Detection Logic Implementation on FPGA 1. Stuck at Fault 2. Memory BIST
4.	Implementation of RISC CPU on FPGA and debugging using Embedded Logic Analyzers.
5.	CW, Pulse, FMCW radar design
6.	Phased array radar design
7.	RCS measurement
8.	Real-time signal acquisition and spectral profile computation
9.	Doppler/speed measurement
10.	Characterization of radar subsystems/ components

Course Code	Course Name	L – T – P	Credits
EERL02	Radar Laboratory II	3-0-0	3
Course Outcomes:			
CO1	Understanding the fundamentals of radar.		
CO2	Understand different pulse compression waveforms using MATLAB		
CO3	Model an adaptive digital beam former using SAR		
CO4	Formulate ISAR images of LSS targets		
CO5	Design and characterization of different types of antennas		
List of experiments:			
Sr. No.	Experiments		
1.	Radar clutter modeling and statistical analysis of various clutter distributions, Realization of N-pulses DLC MTI using FPGA, Analysis of detection performance improvement due to coherent/non-coherent pulse integration using MATLAB.		
2.	Realization of various CFAR using FPGA, Generation and spectral analysis of different pulses compression waveforms using MATLAB.		

3.	Realization of matched filtering operation and detection concept, analyzing the ambiguity diagram for different Radar waveforms, Modeling and simulation of micro-Doppler effect, and processing.
4.	Realization of adaptive Mono-pulse, Kalman, and other tracking algorithms.
5.	Simulating the phased array assisted tracking technique, the Realization of digital and non-adaptive beam forming, and Adaptive array processing using the LMS algorithm.
6.	Modeling an adaptive digital beam former using SAR simulation and a Moving platform (airborne, space-borne, and ship-borne) modeling using SystemVue.
7.	Targets direction finding using IQ signals
8.	Real-time analysis of micro-Doppler T-F imaging
9.	Formulation of ISAR images of LSS targets
10.	Design and characterization of different types of antennas

Course Code	Course Name	L – T – P	Credits
EEDL01	D&S Laboratory I	3-0-0	3
Course Outcomes:			
CO1	Understanding the basics of EM tools		
CO2	Understand Measurements using VNA and SA		
CO3	Knowledge of S-parameters		
CO4	Design and fabricate transmission lines		
CO5	Mini project to design and develop 4-port devices		
List of experiments:			
Sr. No.	Experiments		
1.	Hands-On with EM Simulator (ADS/CST/HFSS): Design and simulate a planar transmission line in an EM simulator		
2.	Measure the S-parameters of a Transmission line using a Vector Network Analyzer (VNA): Understand the function of a VNA		
3.	Calibration of VNA using the Mechanical calibration kit		
4.	Measure parameters (input impedance, VSWR, S-parameters) of microwave passive components such as filters, power dividers, etc.		
5.	Characterize the amplifiers using the spectrum analyzer: Understand the use of the Spectrum Analyzer		
6.	Learn how to prepare the layout of the circuit in IntelliCAD/AutoCAD for production purposes		
7.	Fabricate a prototype (planar microwave component) and measure its performance		
8.	Observe the S-parameter (S_{11}) after terminating a Planer transmission line with different Impedances (open, load, short) and compare it with that obtained in simulations		
9.	Design a planar filter and simulate its performance in terms of S-parameters		
10.	Design a 4-port planar coupler and simulate its performance in terms of S-parameters		

Course Code	Course Name	L – T – P	Credits
EEDL01	D&S Laboratory II	3-0-0	3
Course Outcomes:			
CO1	Understanding the fundamentals of antenna Measurements		
CO2	Understand the Characterization of antennas		
CO3	Knowledge of RF passive components		
CO4	Design Passive probes for EMI		
CO5	Mini project to understand the EMI and EMC		
List of experiments:			
Sr. No.	Experiments		
1.	Radiation pattern measurement using the DAMS controller and its connectivity to the antenna positioner inside the anechoic chamber, to the VNA.		
2.	Measure the antenna gain using the Friis equation and a reference antenna with known gain		
3.	Design two parallel planar transmission lines and observe the coupling between them while changing the spacing between them.		
4.	Integrate the power combiner with the antenna array, and list the performance of the individual network		
5.	Design and develop a microstrip patch antenna and compare simulated and measured results		
6.	PCB Board Level EMC Simulation: Observe the effects of shielding, grounding, etc. in the EM simulator using appropriate probes		
7.	Controlling Crosstalk: Frequency-Domain Perspective Objectives: i) To measure crosstalk in the frequency domain ii) To investigate the factors affecting the crosstalk level		
8.	Characterize a mixer using a source and a spectrum analyzer		
9.	Controlling Radiated Emission from Cable and PCB: To observe the frequency spectrum of the near-field electromagnetic (EM) radiation from cables and printed circuit board (PCB) traces using a near-field probe and a spectrum analyzer		
10.	Study different types of probes of EMI/EMC that are used to measure the EMI (for H-field, E-field).		

Course Code	Course Name	L – T – P	Credits
EECL01	IC design Lab-I: Device Design, FPGA & Front-End Design	3-0-0	3
Course Outcomes:			
CO1	Understanding the fundamentals of Device Design.		
CO2	Design HEMT, HBT, GaN HEMT, and understand its physics		
CO3	Knowledge of FPGA, circuit design using the device designed in an EDA tool		
CO4	Design a circuit, do its verification, and STA		
CO5	Mini project to understand the VLSI design flow from RTL to netlist		
List of experiments:			
Sr. No.	Experiments:		
1	DC characteristics of HEMTs		
2	Logic Simulation of Electronic Circuits.		
3	LDMOS characteristics		
4	Logic Synthesis of Combination Circuits		
5	DC Characteristics of HBTs		
6	Checking and violation of design constraints and mitigating the same in digital circuits.		
7	Power amplifier design using HEMTs		
8	Application of Formal Verification methods in digital circuits		
9	Device physics of GaN HEMTs		
10	Obtain and study the Static Timing Analysis of digital circuits		
11	The Basic FPGA Design Flow 1. To understand the use of Xilinx ISE 2. To understand Xilinx Synthesis Technology or XST. 3. Familiarization with Xilinx Vivado Design Tools.		
12	Familiarization with FPGA Boards 1. Xilinx FPGA Boards (Virtex 6, Kintex7) 2. Implementation of a Full adder, ALU, Memory, and FIFO on an FPGA		
13	Fault Detection Logic Implementation on FPGA 1. Stuck at Fault 2. Memory BIST		
14	Implementation of RISC CPU on FPGA and debugging using Embedded Logic Analyzers.		
15	Use of SPICE for MOSFET modeling and simulation of Digital combinational Circuits.		
16	Schematic gate-level Simulation of Digital combinational circuits		
17	LVS simulation of Digital circuits.		
18	Schematic gate-level Simulation of Digital sequential circuits		
19	Simulation of memory circuits using PSPICE		
20	Mini Project- RTL to Netlist		

Tools used: Synopsys, Cadence, Vivado EDA tools

Course Code	Course Name	L – T – P	Credits
EECL02	IC design Lab-II: Mixed signal-RF IC & Back-End Design Lab	3-0-0	3
Course Outcomes:			
CO1	Understanding the fundamentals of Nano Device Design.		
CO2	Quantum nanotransport & 2D material simulations		
CO3	Knowledge of CTS, Physical design, Floor planning etc.		
CO4	Design an Analog and RF circuit, such as an OP amp circuit.		
CO5	Mini project to understand the VLSI design flow from netlist to GDS		
List of Experiments:			
Sr. No.	Experiments:		
1	Physical Synthesis: Clock Tree Synthesis (CTS)		
2	Physical Synthesis: Placement		
3	Physical Synthesis: Power Net Synthesis (PNS)		
4	Physical Synthesis: Floor planning		
5	Chip Finishing		
6	Parasitic Extraction, STA, Physical Synthesis: Routing		
7	NAND DESIGN: Schematic Entry and Symbol Creation Building the NAND Test Design, Simulation with Spectre, Parametric Analysis, Creating Layout View of NAND Gate, Physical Verification,Creating the Configuration View,Generating Stream Data.		
8	SRAM DESIGN: Schematic Entry and Symbol Creation Building the SRAM Test Design, Simulation with Spectre, Creating Layout View of SRAM, Physical Verification.		
9	Simulation of LNA using ADS/Matlab Software.		
10	Simulation of Power Amplifier using ADS/Matlab Software.		
11	Simulation of Mixer using ADS Software.		
12	Characterization of LNA and Power Amplifier using FieldFox		
13	Characterization of MOSFET Parameters in Subthreshold Region		
14	Design and Simulation of a Low-Power Operational Amplifier		
15	Design and Analysis of a High-Speed Comparator		
16	Design and Simulation of a Low-Power Successive Approximation Register (SAR) ADC		
17	Implementation and Analysis of a Phase-Locked Loop (PLL) for High-Speed Clocking		

Tools used: Synopsys, Cadence, Vivado EDA, Matlab, Quantumwise ATK, ADS

Course Code	Course Name	L – T – P	Credits
EECL03	IC design Lab-III: Advanced SoC-CAO & Back-End Design Lab	3-0-0	3

Course Outcomes:	
CO1	Understanding the fundamentals of Nano Device Design.
CO2	Quantum nanotransport & 2D material simulations
CO3	Knowledge of CTS, Physical design, Floor planning, etc.
CO4	Design a Analog and RF circuits such as OP amp circuit.
CO5	Mini project to understand the VLSI design flow from netlist to GDS
List of Experiments:	
Sr. No.	Experiments:
1	Verilog Simulation and RTL Verification a) Memory b) Clock Divider and Address Counter c) n-Bit Binary Counter and RTL Verification
2	Basic Verification environment for FIFO/UART
3	Verification Planning for FIFO/UART a) Development of the test cases as per the verification plan b) Generation and Analysis of Code coverage Reports
4	Writing assertions for FIFO
5	Typical Soc Design and Emulation on FPGA Platform
6	Write an example to demonstrate the user defined data type enum, struct, struct packed, union, typedef and string, the static array, multi-dimensional static array, dynamic array, associative array and queue type array, demonstrate a simple interface.
7	Write an example to demonstrate class constructor, inheritance, encapsulation, and polymorphism, randomization, rand casec, rand sequence, rand sequence abort., DPI (Direct Programming Interface), both sv to c and c to sv., semaphore, mailbox, virtual interface
8	Create SV based test and class-based test environment for a 1-bit adder.
9	Create a class-based test environment for RAM and FIFO memory given.
10	Create coverage and assertions for the decade counter and the ones counter.
11	Create coverage and assertions for the RAM previously created counter.
12	Create coverage and assertions for the FIFO memory previously created counter.
13	Physical Synthesis: Clock Tree Synthesis (CTS)
14	Physical Synthesis: Placement
15	Physical Synthesis: Power Net Synthesis (PNS)
16	Physical Synthesis: Floor planning
17	Chip Finishing
18	Parasitic Extraction, STA, Physical Synthesis: Routing
19	Coding of simple RISC-V programs in assembly and emulating them in Spike or QEMU simulator (Tools: QEMU, RISCV SPIKE), Modelling OF 32 bit single cycle RISCV CORE IN SYSTEM C/Verilog/Bluespec, and run baremetal software code in it (SYSTEM C SIMULATORS LIKE XCELIUM from cadence)
20	Modelling of a 32-bit 3-stage pipelined RISC-V CORE IN SYSTEM C/Verilog/Bluespec

21	MODELLING Cache Controllers AND BRANCH PREDICTORS IN C/SYSTEM C
22	MODELLING OF VARIOUS SYSTOLIC ARRAY ARCHITECTURES IN SYSTEM C and performing performance benchmarking
23	Implementation of Accelerators for Various Mathematical Problems and performing performance benchmarking

Tools used: Synopsys, Cadence, Vivado EDA, Matlab, Quantumwise ATK, ADS

Course Code	Course Name	L – T – P	Credits
EECL04	MEMS Design Lab	3-0-0	3
Course Outcomes:			
CO1	Understanding the fundamentals of MEMS Design.		
CO2	Understand Microfabrication Techniques and Processes		
CO3	Knowledge of CTS, Physical design, Floor planning etc.		
CO4	Design a Analog and RF circuits such as OP amp circuit.		
CO5	Mini project to understand the VLSI design flow from netlist to GDS		
List of Experiments:			
Sr. No.	Experiments:		
1	Physical Synthesis: Clock Tree Synthesis (CTS)		
2	Physical Synthesis: Placement		
3	Physical Synthesis: Power Net Synthesis (PNS)		
4	Physical Synthesis: Floorplanning		
5	Chip Finishing		
6	Parasitic Extraction, STA, Physical Synthesis: Routing		
7	NAND DESIGN: Schematic Entry and Symbol Creation Building the NAND Test Design , Simulation with Spectre, Parametric Analysis ,Creating Layout View of NAND Gate ,Physical Verification,Creating the Configuration View,Generating Stream Data.		
8	SRAM DESIGN: Schematic Entry and Symbol Creation Building the SRAM Test Design, Simulation with Spectre, Creating Layout View of SRAM, Physical Verification.		
9	Simulation of LNA and power amplifier		
10	Characterization of MOSFET Parameters in Subthreshold Region		
11	Design and Simulation of a Low-Power Operational Amplifier		
12	Design and Analysis of a High-Speed Comparator		
13	Design and Simulation of a Low-Power Successive Approximation Register (SAR) ADC		

14	Implementation and Analysis of a Phase-Locked Loop (PLL) for High-Speed Clocking
15	Design a MEMS Cantilever Beam and compare between Point Load & Surface Load
16	Design a MEMS Cantilever Beam having Multilayers
17	Detection of HIV-virus by Micro-Cantilever
18	MEMS Capacitance & Microgripper
19	Joule Heating of Microactuator
20	Microresistor Beam
21	Pressure Sensor
22	MEMS Comb Drive Actuator

Tools used: Synopsys, Cadence, Vivado EDA, Matlab, Quantumwise ATK, ADS, Coventorware, MEMS+ tools

*Department of Applied
Chemistry, Energy and
Environment*

ABOUT THE DEPARTMENT:

The Department of Applied Chemistry started in 1952 with the aim to impart education and training to DRDO work force in the area of high energy materials and propellants. Over the years Department has moved on to cater to the need of DRDO and civilian students in order to bring the DRDO achievements closer to our society. The Department's aim is to contribute to our understanding of the chemical world through excellence in observational, theoretical and experimental science and to extend quantitative and other appropriate methodologies to address problems in the fields of applied chemical science. In Applied Chemistry, we are endowed with faculties who are dedicated teachers and distinguished researchers that carry out cutting-edge research in all modern areas of Applied Chemistry, as well as in inter-disciplinary areas like nanoscience and technology, high energy materials, polymer science and technology etc.

The first PhD of DIAT (DU) was from the Department of Applied Chemistry and currently it is amongst the Departments guiding very high number of PhD scholars and research publications in DIAT. In addition to PhD, there are numbers of M. Tech. students carrying their PG education. We provide a vibrant and creative learning environment for our students and researchers. We also participate extensively in R&D for various DRDO labs and industries. Dept of Applied chemistry has organized about 20 national, international conference and workshop as well as many customized courses for Ministry of Defence including Tri-services.

In recent times, the Department has made significant contributions towards revenue generation through grant-in-projects and customized courses. Currently the dept is conducting three programme viz; MSc in Applied Chemistry, MSc in Food Technology and MTech in Nanoscience and Nanotechnology. The students of the dept after completing the degrees are well placed in industry and also undertake higher studies such as PhD in India and abroad.

M.Tech. in Nano Science & Technology

Description about the programmes:

To impart in-depth and intensive training in theory, testing and practice of chemical science especially in Nanoscience Technology, Chemical Science & Technology & High Energy Materials (HEM), Polymers and Composites to the young scientists of DRDO, other agencies of Ministry of Defence and fresh engineers / postgraduates. The programme covers various disciplines like chemical science & engineering, High Energy materials, polymers and composites, chemistry of nano materials and their applications. The course is suitable for DRDO scientists, service officers and civilians.

Objective

- To provide students with a strong technical education for meeting the modern requirements of technological challenges for chemical industry and academia.
- To train student and provide them ability to gain knowledge in multidisciplinary area
- To impart practical knowledge in the field of nanoscience, nanotechnology, materials chemistry, physics and electronics.
- To produce market ready technical work-force

Eligibility

BE / B.Tech in any discipline of Engineering, M.Sc. in any discipline of Science.

Qualification: 55% marks or 5.5 CGPA in the qualifying examination as indicated against the disciplines concerned and valid GATE Score Certificate. The qualification should have been obtained from a recognized (by UGC) University / Deemed University / Institution in India.

The candidates who are in the final semester of their degree are eligible to apply; Mark sheet up to the last semester should be enclosed. Provisional certificate in such cases along with Mark sheet of the final semester are required to be submitted before commencement of program.

PROGRAMME OUTCOMES (POs)

- PEO1.** To prepare the graduates for the futuristic cutting-edge technologies at nanoscale
- PEO2.** To develop scientific attitude and skills for applying nanotechnology for advanced application
- PEO3.** To train the graduates to various methods, routes, techniques, instruments for analysis
- PEO4.** To generate technically skilled manpower for innovations in the field of nanotechnology
- PEO5.** To generate human resource for effective scientific contribution for society (both civil and defence sector) through exploiting nanotechnology

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Tech. (Nanotechnology) programme, graduates will be able to

PSO1: Evolving crucial understanding of Nanochemistry, nanophysics and nanoelectronics covering fundamental of Physics, Chemistry of solids, Quantum physics of nanostructures, Nano-electronics and Nano-photonics and nanobiotechnology.

PSO2: Concentrating on specific skills on synthesis of nanomaterials, thin and thick films deposition/fabrication and their characterization

PSO3: Solve research gaps and provide solutions for advancement of science and technology through laboratory practices

PSO4: To create competent scientific work-force through research/product/patent oriented dissertation.

a. Credit Structure

PSC: Program Specific Core **PE:** Professional Elective **PSL:** Program Specific Lab

Semester I				
Sr.No.	Course Type	Course Code	Course	Credits
1	PSC-1	NT-601	Introduction to Nano Science & Technology	3
2	PSC-2	NT-602	Synthesis and Characterization of Nanomaterials	3
3	PSC-3	NT-603	Nanotechnology for Defense and Industrial Applications-I	3
4	PSC-4	NT-604	Nano materials for Energy and Environment	3
5	PE-I		Elective – I from Applied Chemistry, Metallurgical and Materials, Applied Physics, Dept of Electronics Engg & School of Energy & Environment	3
6	PSL	NT612	Laboratory Practical I	3
7	PGC	PGC-601	Research Methodology and IPR	2
			Total	20

Semester II				
Sr.No.	Course Type	Course Code	Course	Credits
1	PSC-5	NT 621	Nanobiotechnology	3
2	PSC-6	NT 622	Nanotechnology for Defense and Industrial Applications-II (NBC Warfare: Concepts & Remediation)	3
3	PE-II	E2	Elective – II from Metallurgical and Materials, Applied Physics, Dept of Electronics Engg & School of Energy & Environment	3
4	PE-III	E3	Elective – III from Metallurgical and Materials, Applied Physics, Dept of Electronics Engg & School of Energy & Environment	3
5	PE-IV	E4	Elective – IV from Metallurgical and Materials, Applied Physics, Dept of Electronics Engg & School of Energy & Environment	3
6	PSL	NT613	Laboratory Practical II	3
7	PGC	PGC-602	Communication Skills & Personality Development	2
			Total	20

Semester III				
Sr.No	Course Code	Course Type	Course	Credits
1	NT-651	Dissertation and Seminar Phase - I	Research Thesis I	20

Semester IV				
Sr.No	Course Code	Course Type	Course	Credits
1	NT-652	Dissertation and Seminar Phase - II	Research Thesis II	20

Course Matrix

Sr No	Program Specific Core	Professional Electives	Program Specific Lab	NPTEL/Swayam Courses
01	NT601: Introduction to Nano Science & Technology	AP-601 (Sem-I) : Fundamental of sensors AND THE COURSES LISTED IN TABLE 1.	NT612 Laboratory Practical I	Biomass Conversion and Biorefinery
02	NT602: Synthesis & Characterization of Nanomaterials	NT-623: (Sem-II) Nano-electronics (IT, AI, ML)	NT613 Laboratory Practical II	Environmental Quality Monitoring & Analysis
03	NT-603: Nanotechnology for Defense and Industrial Applications-I	NT: 624 (Sem-II) Nano-Safety Health and Hazard Management AND THE COURSES LISTED IN TABLE 1.		Physico-chemical processes for wastewater treatment
04	NT604: Nano materials for Energy and Environment	MM610: Nanomaterials and their applications		
05	NT621: Nanobiotechnology	MM612: Polymer Blends and Nanocomposites		

06	NT622: Nanotechnology for Defense and Industrial Applications-II (NBC Warfare: Concepts & Remediation)	ME636: MEMS - Design, Fabrication, and Characterization		
07		AP620: (Sem-II) Nano photonics		
08		AP613: (Sem-I) Semiconductor Photonic Devices		
09		MM602: (Sem-I) Materials Characterization		

Note: Students have to opt for Program-Specific Core courses from the Department only. Professional Electives can be courses from the Department, Other schools/departments, or NPTEL courses. A maximum of 6 credits can be opted by students as a Professional Elective from the list of Online courses on NPTEL/SWAYAM during Sem I and Sem II. It is recommended to take PE-I and PE-II from AC only. The list of Swayam/NPTEL will be reviewed/modified by the school every year.

b. List of NPTEL Approved by BoS for M.Tech NSNT(3 Credit)

Name of Course	Instructor	Institute	Duration	Domain
Biomass Conversion and Biorefinery	Prof. Kaustubha Mohanty	IIT Guwahati	12 Weeks	Energy and Environment
Environmental Quality Monitoring & Analysis	Prof. Ravi Krishna R	IIT Madras	12 Weeks	Energy and Environment
Physico-chemical processes for wastewater treatment	Prof. Vimal Chandra Srivastava	IIT Roorkee	12 Weeks	Energy and Environment

TABLE 1. List of Electives subject for Semester I

Sl. No.	Course Code	Course Name

1	AP 601	Fundamentals of Sensors
2	AP 620	Nanophotonics
3	MM 602	Materials Characterization
4	MM 607	Concepts of Polymer and composite
5	MM611	Nanomaterials and Their Applications
6	MM 614	Biomaterials
7	AP 613	Semiconductor Photonic Devices
8	Electives from other Department, MOOC/NPTEL courses	

TABLE 2. List of Electives subject for Semester II

NT: 623: (Sem-II) : Nano materials for Energy and Environment
NT-624: (Sem-II) Nano-Safety Health and Hazard Management
AP-620: (Sem-II) Nano photonics
TM-610 (Sem-II) : Leadership & Organizational Behaviour :Technology Management Course
TM-602: (Sem-II): AI in Management: Technology Management Course

DETAILED SYLLABUS

Course	Course Name Code	Credits
NT-601	Introduction to Nano Science & Technology	3

Course Objectives: The main objectives of this course are to:

1. To understand fundamental concepts of chemistry & physics for nanoscience and technology
2. To gain knowledge on size dependent various physical and chemical properties

UNIT I: Introduction to Nanotechnology, Scientific Revolutions, Nanotechnology and Nanomachines, Chemical bonding & theories (e.g. Valence band & Molecular Orbital), atomic structure- energy — molecular and atomic size and their properties. Forces between atoms and molecules, particles and grain boundaries, surfaces — strong intermolecular forces, Van der Waals and electrostatic forces between surfaces, covalent and coulomb interactions

UNIT II: Solid State Physics (Overview): Amorphous, crystalline, polycrystals, symmetry, Unit Cells, Crystal Structures (Bravais Lattices), Crystallographic Planes, Miller Indices, Electronic Properties, Classification of materials: Metal, Semiconductor, Insulator, Band, structure.

UNIT III: Implications of nano size on physical and chemical properties: Density of States, large surface to volume ratio, surface functionalization, tunability of properties, Chemistry of solid surfaces, Confinement and transport in nanostructure.

UNIT IV: Nanoparticles, nano-clusters, nanotubes, nanowires and nanodots. Quantum dots, quantum wires and quantum wells, Semiconductor and metal nanostructures, carbon nanotubes, nanofluids, nanoink, hybrid nano materials and nano composites.

Reference Books

- Pradeep, T., Nano: The Essentials, McGraw Hill Publishers, Mumbai, 2007.
- Charles P. Poole, Jr. Frank J. Owens, Introduction to Nanotech., John Wiley & Sons 2003.
- Vladimir V. Mitin, Viatcheslav A. Kochelap, Viacheslav Aleksandrovich Kochelap Introduction to Nanoelectronics: Science, Nanotechnology, Cambridge University — 2008
- Pignataro, B., Tomorrow's Chemistry Today—Concepts in Nano science, Organic Materials, and Environmental Chemistry. Wiley-VCH. Royal

Course Outcomes On the successful completion of the course, student will be able to:

1. To understand the fundamental concepts of nanoscience
2. To apply the basic concepts of physics, chemistry and biology concepts to understand the advanced concepts of nanoscience
3. To influence of size and morphology and other factors on various properties of materials.
4. To understand various applications

Course Code	Course Name	L	Credits
NT-602	Synthesis & Characterization of Nanomaterials	3	3

Course Objectives: The main objectives of this course are to:

1. To understand preparation procedures also the various factors that affects the size and morphology of crystallites.
2. To gain knowledge on current status, future trends and scope for research.
3. To study various spectroscopic and analytical methods for characterization of nanomaterial

UNIT I: Fundamentals of nucleation and growth: Physical Chemistry of solid surfaces, Crystallization, Interactions between particles. Top down and bottom-up approach of synthesis: Physical and Chemical routes.

UNIT II: Physical Route for synthesis of Nanomaterials: Mechanical (high energy ball milling, physical evaporation methods (Plasma method, Pulse Laser method, spray pyrolysis), sputter deposition, Chemical Vapour Deposition, Arc Deposition etc

UNIT III: Chemical Routes for Synthesis of Nanomaterials: Chemical precipitation and coprecipitation; Sol-gel synthesis; Microemulsions or reverse micelles; Solvothermal synthesis; Thermolysis routes, Microwave heating synthesis; Sono-chemical synthesis

UNIT IV: DIFFRACTION TECHNIQUES

Concepts of diffraction, scattering and radiation-matter interactions, X-ray diffraction. Powder diffraction, phase identification, Scherrer formula, strain and grain size determination

UNIT V: MICROSCOPY AND IMAGING:

Fundamentals of Imaging: magnification, resolution, depth of field and depth of focus, etc. Basic principle and components of SEM/EDAX, and TEM./EDAX, Electron diffraction in TEM and its applications, AFM

UNIT VI: - SPECTROSCOPIC TECHNIQUES & THERMAL ANALYSIS:

X ray Photon Spectroscopy, FTIR, Raman spectroscopy, UV-visible, PL, TGA/DSC

Course Outcomes

1. To understand fundamental concepts in materials preparation with various morphologies
2. To apply the gained subject knowledge towards understanding the mechanisms involved physical, chemical and mechanical routes
3. To analyze acquired knowledge and understanding on effect of grain morphology and its needs for technological advancements
4. To understand advanced microscope techniques.
5. To obtain knowledge on characterization by thermal and non-thermal techniques

Course Code	Course Name	L	Credits
NT 603	Nanotechnology for Defense and Industrial Applications-I	3	3
Course Objectives: The main objectives of this course are to: 1. To understand the role of nanomaterials for defence applications 2. To understand the role of nanotechnology in sensor, armor protective system, propellants, pyro-techniques, corrosion, fire retardancy, cosmetics, catalysis, pharma, agriculture, food, 3. To understand the application of nano materials in industry			
<u>UNIT I:</u> Introduction to nano-energetic materials; Applications of nano materials in ammunition, energetic materials, Nano-thermites. <u>UNIT II:</u> Nanotechnology in stealth and armor protective system <u>UNIT III:</u> Chemical and biological warfare: Nano materials in detection and decontamination of CW and BW agents <u>UNIT IV:</u> Nano materials in thermoelectric and piezoelectric sensing, nanotechnology in sensor, armor protective system, corrosion, cosmetics, catalysis, pharma, agriculture, food tech. <u>UNIT V:</u> Nano Coating and Nano composites for industrial Application			
Course Outcomes			
1. To understand various applications of nanomaterials in ammunitions and related energetic applications of nanoparticles. 2. To understand the basic difference between nano verses macro particles in terms of their applications. 3. To understand how nanoparticles used in detection and decontamination of chemical and biological warfares. 4. Understand the application of nano particles in industries.			
Reference Books			
1. Nanotechnology for Defence Applications, Narendra Kumar, Ambesh Dixit, Springer, 2019. 2. Nanotechnology for Chemical and Biological Defense, Margaret Kosa-l 2009, Springer 3. Nanotechnology in the Defense Industry: Advances, Innovations and Practical Applications, Madhuri Sharon, Angelica S. L. Rodriguez, Chetna Sharon, Wiley, 2019.			

Course Course Name Code		Credits
NT-604	Nano materials for Energy and Environment	3
Course Objectives: The main objectives of this course are to: 1. To understand fabrication procedures and working principles of devices such as fuel cells, solar cells, hydrogen generation and energy storage. 2. Possible application of nanomaterials in environmental field. 3. To gain knowledge on current status, future trends and scope for research in energy and environment		
<u>UNIT I :- INTRODUCTION</u> Sustainable energy -Materials for energy -Greenhouse effect -CO₂ emission -Energy demand and challenges. <u>UNIT II:-RENEWABLE ENERGY TECHNOLOGY</u> Development and implementation of renewable energy technologies. Nano, micro and meso scale phenomena and devices. Energy conversion, transport and storage. Photovoltaic solar cells. Thermoelectric systems, DSSC- Quantum dots based solar cells., EMI Shielding applications of nanomaterials		

<u>UNIT III:- NANOMATERIALS IN FUEL CELL AND STORAGE TECHNOLOGY</u> Micro-fuel cell technologies, integration and performance for micro-fuel cell systems -thin film and microfabrication methods -design methodologies -micro-fuel cell power sources - Supercapacitors -Specific energy-charging/discharging -EIS analysis. <u>UNIT IV:- HYDROGEN STORAGE</u> Hydrogen storage methods -metal hydrides -size effects -hydrogen storage capacity - hydrogen reaction kinetics -carbon-free cycle-gravimetric and volumetric storage capacities - hydriding/dehydriding kinetics -multiple catalytic effects - <u>UNIT.V:- EMERGINGTECHNOLOGIES FOR ENVIRONMENTAL REMEDIATION AND PHOTOCATALYSIS</u> Use of nanoparticles for environmental remediation and water treatment-Role of dendrimer-single enzyme-nanoparticle and metalloprotein. Case studies and Regulatory needs. Degradation of the dye - nanomaterials based photocatalyst design -kinetics of degradation.

Course Outcomes	
1. To understand fundamental concepts in energy harvesting and storage systems and environmental system 2. To apply the gained subject knowledge on understanding the mechanisms involved in various devices based on nanostructures and environmental system 3. To evaluate and understand the role of nanomaterials effectiveness over the coarse- grained bulk solids, Bioremediation, Removal of bacteria etc. 4. To analyze acquired knowledge and understanding on commercial and technological trends in both energy harvesting and storage devices and environment	
Reference Books	
1. Shantanu Bhattacharya, Avinash Kumar Agarwal, T. Rajagopalan, Nano-Energetic Materials, Springer Nature Singapore Pte Ltd. 2019. 2. Xiaoru Wang, Xi Chen, Novel Nanomaterials for Biomedical, Environmental & Energy, 2018 3. Handbook of fuel cells: Fuel cell tech and applications by Vielstich. Wiley, CRC Press, 2003. 4. Hydrogen from Renewable Energy Sources by D. Infield 2004. 5. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.	

Course Code	Course Name	Credits
NT612	Laboratory Practical I	03
	1. Training on wet-chemical laboratory practices 2. Preliminary exposure to various analytical tools 3. Synthesis of Silver nano-particles by chemical method 4. Synthesis of metal NPs using plant extract 5. Analysis of Noble metal NPs by UV-Visible spectroscopy 6. Sol-gel method for MO NPs 7. Analysis of NPs by XRD 8. Synthesis of II-VI semiconductor nano-particles 9. Synthesis of QDs (CdS/CdSe/CdTe) 10. Analysis of QDs by UV/PL 11. Synthesis of carbon QDs 12. Optical Properties of carbon QDs (UV/PL) 13. Calculation of band-gap energy in semiconductor NPs 14. Industrial/Instructional visit-1	

SEMESTER -II

Course Code	Course Name	Credits
NT-621	Nanobiotechnology	3
Course Objectives: The main objectives of this course are to: 1. Understanding the basic of Biology and Nano science and differentiate between nanomaterials and bulk materials 2. Evaluate and critically review the theoretical and practical aspects of Nano materials application 3. Comprehending the novel function resulted from the nanoscale structures using scientific and technological principles in Nano biotechnology		
UNIT I: Introduction, History & Applications, various definitions and Concept of bio and Nano-biotechnology, Cell-Nanostructure interactions, Proteins, DNA based nanostructure.		
UNIT II: Biological methods for synthesis of nanoparticles, surface functionalization- and plants extracts and microorganism utility in nanomaterials/biomaterials.		
UNIT III: Various applications of Nano-biotechnology, Devices based on nano biotechnology-and their applications, lab on a chip.		
UNIT IV: Biomedicine and applications of Nanotechnology in Drug Delivery and bioinformatics, Nano materials for other biomedical applications		

Course Outcomes

1. Critically assess and outline the nanotechnology for all areas of application
2. Demonstrate the new properties of Nano materials for next generation needs
3. Comprehend the biological response to nanomaterials
4. Understand the concept of drug delivery via nanotechnology
5. Understand the various biomedical applications of nanomaterials

Reference Books

1. Nanobiotechnology: A Multidisciplinary Field of Science, Basma A. Omran, 2020, Springer
2. Nanobiotechnology: Concepts, Applications and Perspectives, Christof M. Niemeyer, Chad A. Mirkin- 2006, Wiley-VCH
3. Microbial Nanobiotechnology: Principles and Applications, Agbaje Lateef, Evariste Bosco Gueguim-Kana, Nandita Dasgupta 2021, Springer.

Course Code	Course Name	Credits
NT 622	Nanotechnology for Defense and Industrial Applications-II (NBC Warfare: Concepts & Remediation)	3

Course Objectives:

1. To understand the principle of NBC
2. Recognize chemical, biological, and radiological (CBR) attack methods.
3. Recognize the need for CBR defense.
4. Identify terms used with CBR
5. Scope of nanomaterials in NBC

UNIT I: Introduction of nuclear science, types nuclear radiations

UNIT II: NUCLEAR SCIENCE: Structure of nucleus, Mass defect, Binding energy, Nuclear reaction, Fission & Fusion nuclear reactions, Controlled & uncontrolled release of nuclear energy, Concepts of critical mass & critical volume, detection techniques of radiations, scope of nanomaterials in detection.

UNIT III: NUCLEAR WEAPONS: Principle, Effects: Blast, thermal and radiation, Nuclear bombs (Fission & Fusion Type) Yield of weapon, Protection against nuclear weapons, detection techniques for radiations and disposal of nuclear wastes, **Radiological** weapon

UNIT IV: CHEMICAL & BIOLOGICAL WEAPONS: Different chemical warfare agents, Their tactical roles / effects, Delivery systems, biological warfare agents & their effects, Protection against biological, chemical warfare, nano-agents and their detection, decontamination of CW and BW agents by nanomaterials.

Course Outcome

1. To understand the types of nuclear radiations
2. To understand the basic of nuclear science w.r.t fission, fusion, controlled and uncontrolled reactions
3. To understand the concept of nuclear weapons
4. Identify terms used with chemical warfare and biological warfare
5. Understand the difference between chemical and biological weapon with different warfare agents.

Reference Books

1. Principles/Effects & Sensitivity, 1994, C. S. Grace, Brasey series
2. Chemical warfare agents, 1992, S.M.Somai
3. Biological weapons, 1999, Joshua Lederberg

Course Code	Course Name	Credits
NT 623	Nano Electronics and IT, AI, ML	3
Course Objectives: The main objectives of this course are to: 1. To understand the basic Electronics and IT, AI, ML for nanotechnology 2. To demonstrate and understand techniques for Electrical, optical and sensoric devices. 3. To understand general information technology, IoT, electrical and electronics techniques.		
<u>UNIT I: IT, AI, ML</u> ➤ Introduction to AI & ML ➤ Data Sets, Feature Engineering, Machine Learning Algorithms ➤ Classification and Regression, Artificial Neural Networks ➤ Deep Learning, Large Language Models and Applications ➤ Augmented Reality, Virtual Reality UNIT-II: ENERGY BAND- SCHRODINGER EQUATION SELF-CONSISTENT SOLUTION: $E(p)$ or $E(k)$ relation, density of states, number of modes, electron density (n), quantum wells, wires, dots, nanotubes, conductivity vs. electron density (n), quantum capacitance, the nano transistor boundary condition, Quasi-Fermi Levels (QFL's), Landauer formulas, electrostatic potential, Boltzmann Equation, Spin Voltages. Hydrogen atom, method of finite differences, wave equation, differential to matrix equation, dispersion relation, counting states, Beyond 1-D, Basis functions, Graphene, Reciprocal Lattice / Valleys, self-consistent field (SCF) procedure. UNIT-III: NON-EQUILIBRIUM GREEN'S FUNCTION (NEGF) FORMALISM: Semiclassical model, quantum model, equations, current operator, scattering mechanisms, transmission, resonant tunneling, dephasing, local density of states [LDOS]. <u>UNIT IV:</u> Device Fabrication e.g. Solar cells, LEDs, EMI by VNA, Thermoelectric Generators, Resistive Sensors, Optical Sensor, Chemical Sensors and diagnostics from Physics, Chemistry and Electronics		
Course Outcomes		
1. To understand the IoT, AI and ML in Nanomaterials and Nanotechnology. 2. To obtain knowledge on electrical and magnetic characterization techniques. 3. To obtain knowledge on Practical Applications of nanomaterials 4. To learn methods for fabrication of thin/thick films, and conductive layers		
Text Books ➤ Russel and Norvig, "Artificial Intelligence : A Modern Approach", 4th Edition, Pearson. ➤ Steven Lavalley, "Virtual Reality". Cambridge University Press, 2023		

Reference Books

1. Russel and Norvig, "Artificial Intelligence : A Modern Approach", 4th Edition, Pearson.
2. Steven Lavalle, "Virtual Relity". Cambridge University Press, 2023

Course Code	Course Name	Credits
NT 624	Nano-Safety, Health & Hazard	3
Course Objectives: The main objectives of this course are to: 1. To understand the principles of standards and regulations of nano-safety related to handling, storage and health hazards 2. Know prerequisites of the safety principles in management of modern laboratories. 3. Be able to use these principles and methods in analyzing and solving problems of work /production/application place		
<u>UNIT I: CHEMICAL SAFETY:</u> Standards and regulations of chemical safety in Industries or Laboratories, Storage of hazardous chemicals, Compatibility and classification codes, Chemical risk analysis and management, Fire triangle and Handling of Toxic, Industrial Gases		
<u>UNIT II: HAZARD MANAGEMENT:</u> HAZOP and HAZAN techniques, Hazard in manufacture, Hazard prevention measures, Disposal of hazardous materials		
<u>UNIT III: Nano-toxicity and Nano-safety & health :</u> Classifications of nano-toxicity and safety, precautions, remediation and implementation, Nano materials safety, handling & demonstration of air-sensitive, pyrophoric and toxic chemicals		
<u>UNIT IV: Protection from nanomaterials hazards,</u> Assessment of human factors, Health & Environment safety		
(Tutorials/ Practical's/ Seminars) 1. Handling and demonstration of air sensitive, pyrophoric and toxic chemicals 2. Monitoring of effluents through Gas chromatography / Ion chromatography		

Course Outcomes
1. Aware and about the risks and hazards related to occupational health. 2. Get acquainted with the various causes and conducts responsible for unsafe environment. 3. Responsible for minimizing the accidents in work environment. Develop a positive attitude to solve the concerning the principles of sustainable development. 4. Realize the basics of Occupational Health Hazards. 5. Define industrial hygiene and principles. 6. Familiarizes with Process Safety Management (PSM) as per OSHA
Reference Books
1. <u>Safety and accident prevention in chemical operations John Wiley and sons, New York 1982</u> 2. Technical guidance for hazard analysis USEPA, FEMA, USDOT, 1987 3. Nanotechnology Environmental Health and Safety: Risks, Regulation and Management: M. Hull, D. Bowman, Elsevier, 2010 4. Manual on emergency preparedness for chemical hazard, Ministry of Environment and Forest, Govt. of India, New Delhi, 1989.

Course Code	Course Name	Credits
NT613	Laboratory Practical II	03
	1. Technique(s) for thin film deposition of NPs 2. Nano-particles/Polymer composites and their electrical measurements 3. EMI shielding behaviour of NPs 4. I-V characteristic studies of semiconductors NPs 5. Gas sensing through MO NPs 6. Photocatalysis Experiments using NPs 7. Degradation of explosive/energetic chemicals using NPs 8. THz measurement involving NPs 9. Experiments related to nano-electronics 10. Experiments related to nano-electronics 11. Fabrication technique for QDs LED 12. Experiments related to nano-biotech 13. Industrial/Instructional visit-2	

M.Tech. Renewable Energy

The energy obtained through renewable resources such as sunlight, wind, rain, tides, waves, and geothermal heat is called Renewable Energy. It is opposite to the fossil fuels, which are being used enormously than they are being replenished. Renewable energy resources exist over wide geographical areas, in contrast to fossil fuels, concentrated in a limited number of countries. Therefore, it is rapidly gaining importance and becoming efficient and cheaper, and their share of total energy consumption is increasing. Deployment of renewable energy and energy efficiency technologies results in significant energy security, climate change mitigation, and economic benefits. Renewable energy technology is also suited to rural and remote areas, where energy is often crucial in human development.

Stakeholders:

- (i) Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments
- (ii) Graduates in the relevant field of science/technology from recognized Universities across the country.

Eligibility for Students:

BE/ B.Tech. in Energy/ Mechanical/ Chemical/ Civil/ Environmental/ Computer Science/ Electrical/ Electronics/ Biotechnology/ Full-time M.Sc. in all branches of Chemistry & Physics/ Graduation in any relevant discipline of Science and Engineering.

Organization: The M. Tech. program is of four-semester duration. In each of the first three semesters there are seven theory courses. There will be three continuous evaluation examinations and a final semester examination for every course. At the end of the final semester, the student submits a dissertation and makes a presentation about the work carried out by him/her on the project, which is evaluated by the Internal and External examiners. Course syllabus is updated periodically to keep pace with the contemporary technological advancement.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO1: Graduates will be developing skill set in the field of research in renewable energy sectors.

PEO2: Graduates will acquire interdisciplinary knowledge required to get established as an entrepreneur in renewable energy.

PEO3: Graduates will showcase professional, social, and ethical responsibilities in implementing renewable and sustainable energy solutions.

PROGRAMME OUTCOMES (POs)

PO1: An ability to carry out Research and development work to solve practical / industry problems.

PO2: An ability to write and present a substantial technical report/document.

PO3: An ability to demonstrate mastery over the area as per the specialization of the program which will be beyond the program scheme.

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M.Tech (Renewable Energy) program, graduates will be able to

PSO1: Ability to work in contemporary and futuristic renewable energy research and being industry centric.

PSO2: Ability to develop cutting edge technologies for harnessing renewable energy in multi-dimensional applications.

c. Credit Structure PSC: Program Specific Core **PE:** Professional Elective **PSL:** Program Specific Lab

Semester I				
Sr.No.	Course Type	Course Code	Course	Credits
1	PSC-1	SE-601	Fundamentals of Energy Studies	3
2	PSC-2	SE-602	Bioenergy Systems	3
3	PSC-3	SE-603	Hydrogen Energy	3
4	PSC-4	SE-605	Solar Energy Systems	3
5	PE-I		Professional Elective (SEES/Allied Depts/NPTEL)	3
6	SE616L	SE-616	Renewable Energy Laboratory I	3
7	PGC	PGC-601	Research Methodology and IPR	2
			Total	20

Semester II				
Sr.No.	Course Type	Course Code	Course	Credits
1	PSC-5	SE-607	Wind and Hydro Energy Systems	3
2	PSC-6	SE-608	Geothermal and Ocean Energy	3
3	PE-II		Professional Elective (SEES/Allied Depts/NPTEL)	3
4	PE-III		Professional Elective (SEES/Allied Depts/NPTEL)	3
5	PE-IV		Professional Elective (SEES/Allied Depts/NPTEL)	3
6	SE617L	SE-617	Renewable Energy Laboratory II	3
7	PGC	PGC-602	Research Methodology and IPR	2
			Total	20

Semester III				
Sr.No	Course Code	Course Type	Course	Credits
1	SE-651	Dissertation and Seminar Phase - I	Research Thesis I	20
Semester IV				
Sr.No	Course Code	Course Type	Course	Credits
1	SE-651	Dissertation and Seminar Phase - II	Research Thesis II	20

Course Matrix:

Sr No	Program Specific Core	Professional Electives	Program Specific Lab	NPTEL/Swayam Courses
01	SE-601: Fundamentals of Energy Studies	SE-604: Waste to Energy	SE616L Renewable Energy Laboratory I	Biomass Conversion and Biorefinery
02	SE-602: Bioenergy Systems	SE-606: Renewable Energy and Environmental Sustainability	SE616L Renewable Energy Laboratory II	Environmental Quality Monitoring & Analysis
03	SE-603: Hydrogen Energy	SE-610: Integrated Energy Systems		Heat Transfer
04	SE-605: Solar Energy Systems	SE-611: Rural Electrification Technologies		Physico-chemical processes for wastewater treatment
05	SE-607: Wind and Hydro Energy Systems	SE-612: Energy Storage and Transport Systems		Renewable Energy Engineering: Solar, Wind And Biomass Energy Systems
06	SE-608: Geothermal and Ocean Energy	SE-613: Energy Auditing and Management		Climate Change Science
07		SE-614: Energy Modelling and Simulation		Environmental Geosciences
09		SE-615: Smart Grid		Groundwater hydrology and management
10		SE-628: Battery and Fuel Cell Technology		Non-conventional energy Resources

11		SE-633: Energy Efficient Materials		Rural Water Resources Management

Note: Students have to opt for Program-Specific Core courses from the School only. Professional Electives can be courses from the School, Other schools/departments, or NPTEL courses. A maximum of 6 credits can be opted by students as a Professional Elective from the list of Online courses on NPTEL/SWAYAM during Sem I and Sem II. It is recommended to take PE-I and PE-II from SEES only. The list of Swayam/NPTEL will be reviewed/modified by the school every year.

d. List of NPTEL Approved by BoS for M.Tech Renewable Energy (6 Credit)

Name of Course	Instructor	Institute	Duration	Domain
Biomass Conversion and Biorefinery	Prof. Kaustubha Mohanty	IIT Guwahati	12 Weeks	Energy and Environment
Environmental Quality Monitoring & Analysis	Prof. Ravi Krishna R	IIT Madras	12 Weeks	Energy and Environment
Heat Transfer	Prof. Ganesh Viswanathan	IIT Bombay	12 Weeks	Energy and Environment
Physico-chemical processes for wastewater treatment	Prof. Vimal Chandra Srivastava	IIT Roorkee	12 Weeks	Energy and Environment
Renewable Energy Engineering: Solar, Wind And Biomass Energy Systems	Prof. Vaibhav Vasant Goud Prof. R. Anandalakshmi	IIT Guwahati	12 Weeks	Energy and Environment
Climate Change Science	Prof. J.Srinivasan	IISc Bangalore	12 Weeks	Energy and Environment
Environmental Geosciences	Prof. Prasoon Kumar Singh	IIT Kharagpur	12 Weeks	Energy and Environment
Groundwater hydrology and management	Prof. Pennan Chinnaamy	IIT Bombay	12 Weeks	Energy and Environment
Non-conventional energy Resources	Prof. Prathap Haridoss	IIT Madras	12 Weeks	Energy and Environment
Rural Water Resources Management	Prof. Pennan Chinnaamy	IIT Bombay	12 Weeks	Energy and Environment

e. Detailed Syllabus

SE-601: Fundamentals of Energy Studies

Type: PSC-I

Course Outcomes:

CO-1:	Understand the domain of Energy Science and Technology and various form of energies
CO-2:	Analyse and understand various Power Generation Basics
CO-3:	Illustrate and classify heat exchangers
CO-4:	Identify technical details Energy Consuming Systems
CO-5:	Know about the Energy related organizations and Government Bodies

Syllabus

Units	Syllabus Details	Hrs
Unit I	Energy Science & Technology Forms of Energy, Advantages and Limitations, Mechanical Energy, Chemical Energy and Fuels, Nuclear Energy, Hydro Energy, Renewable Energy, Energy Demand- Efficiencies of various Energy production. Thermodynamic laws governing Energy Transfer	9
Unit II	Power Generation Basics Combined Heat and Power Basics: Steam turbine-based power generation: Rankine cycle, Cogeneration, Waste heat recovery systems, Gas turbine and Brayton cycle analysis, IC Engines, and basic cycles analysis	8
Unit III	Energy Transfer System Heat Exchanger Basics- Counter/ Cross/ Parallel flow, Condensers/ Evaporators, Heat loads, efficiency, and effectiveness.	
Unit IV	Energy Consuming Systems	9

	Introduction to Refrigeration, VCRS and VARS, Ideal Properties of Refrigerant, Ph-Ts diagrams, Psychrometry, Air-conditioning fundamentals, Central AC, Split AC, and Window AC systems.	
Unit V	Governing Bodies: Nodal Agencies for power generation, Ministry of Power, Role – Ministry of New and Renewable Energy Sources, Role, other implementing agencies, Energy Auditing and Management, Energy Conservation Act, Bureau of Energy Efficiency, PCRA, Schemes–Policies, Planning	9

Text Books:

- 1.Mehta D.P. and Albert Thumann, “Handbook of Energy Engineering”, River Publisher, 8th Edition, 2022
2. H. L. Wills and Walter G. S., “Distributed Power Generation”, CRC, 2023
3. Ayhan Demirbas, “Biofuels”, Springer, 2009

References:

1. Fundamentals and Applications of Renewable Energy, 1st Edition, Tata Mc Grow Hill, 2020
2. Aldo Viera da Rosa, “Fundamentals of Renewable Energy Processes”, ELSEVIER, 2005
3. Rai, G.D., "Non-Conventional Sources of Energy", Khanna Publishers, Delhi 1995.
4. Rao S, Parulekar B.B, “Energy Technology – Non conventional, Renewable and Conventional” Khanna Publishers, 1999.
5. H.G. Stoll, Least Cost Electrical Utility / Planning, John Wiley & Sons, 1989.

SE-602: **Bioenergy Systems**

Type: PSC-II

Course Objectives:

CO-1:	Understand current Bio energy status of world and India
CO-2:	Interpret the technical details of Bio mass energy systems

CO-3:	Perform classification of different types of stoves and burners
CO-4:	Analyse the Bio gas plants and technical details of bio gas production
CO-5:	Identify and explain different Bio mass gasifier systems

Syllabus

Units	Syllabus Details	Hrs
Unit I	Bio Energy Resources and potential, World Bio Energy Potential, India's Bio Energy Potential, Current Technology and Research Status, Economic considerations in biomass resource assessments,	9
Unit II	Feedstocks, Conversion technologies to electricity, heat, and liquid and gaseous fuels, Technology of Biomass gasification, Direct Combustion, Pyrolysis and Liquefaction, Bio-Chemical Conversion: anaerobic digestion, Chemical conversion process: hydrolysis and hydrogenation	8
Unit III	Chemical conversion processes: Biodiesel production, different types of feedstock, extraction process, mechanism of transesterification, fuel characteristics of biodiesel, green diesel synthesis from bio-based feedstocks and their applications	9
Unit IV	History, Principle, Design of Biomass Gasifiers, updraft gasifier, down draft gasifier, zero carbon biomass gasification plants, Gasification of plastic-rich waste, applications for cooking, electricity generation, Biomass integrated gasification/combined cycles systems.	9
Unit V	Technology of Bio-gas production, Biogas Plants, Digester types, Digester design, Bio gas plants, Bio-gas as fuel for transportation, Lighting, Running Dual Fuel Engines, Electricity generation, Bio gas Bottling Plant Technology, Application of Bio gas slurry in agriculture, Design of Biogas for cold climates	9

References:

1. KC Khandelwal, SS Mahdi, Biogas Technology - A Practical Handbook , Tata McGraw Hill, 1986
2. RC Maheswari, Bio Energy for Rural Energisation , Concepts Publication, 1997

3. J Twidell and T Weir, Renewable Energy Resources, Taylor and Francis (Ed), New York, USA, 2006
4. B Sorensen, Renewable Energy, 2nd Ed, Academic press, New York, 2000
5. G Boyle (Ed), Renewable energy: Power for a sustainable future, Oxford, OUP, 1996

SE-603: Hydrogen Energy

Type: PSC-III

Course Objectives:

CO-1:	Understand the basic concepts of hydrogen as a fuel
CO-2:	Identify different types of fuel and their characteristics
CO-3:	Analyse and understand technical details of coal and their use as energy source
CO-4:	Illustrate the classification of gaseous fuels
CO-5:	Analyse and understand combustion process and emission from different fuels

Syllabus

Units	Syllabus Details	Hrs
Unit I	Introduction of gases, history of hydrogen, chemical and physical properties of hydrogen and helium, the hydrogen cycle, technology challenges, MSDS of hydrogen, hydrogen color codes.	9
Unit II	Basics of fuels: Modern concepts of fuel, Solid, liquid and gaseous fuels, composition, basic understanding of various properties of fuels. Hydrogen fuel driving thermonuclear fusion energy, Thermonuclear fusion reactions, Rates of thermonuclear reactions, Advantages of small nuclear modular reactors (SMRs).	8
Unit III	Hydrogen Production: Coal as a source of hydrogen energy, Steam reforming, (Partial oxidation process, Design Layout) Thermochemical Water Splitting (Theory, 2/3/4 step process cycles), Electrolysis of water	9

	(Fundamentals, Alkaline and solid polymer electrolysis), Photocatalytic Water Splitting (Steps in Photocatalytic process, Photocatalytic material requirement)	
Unit IV	Hydrogen gas storage and Transport: Phase Diagram of Hydrogen, High Pressure Gas Cylinders, Hydrogen Adsorption (Physio-sorption and Chemisorption, Adsorbent materials), Liquid Hydrogen, Cryogenics, Liquefaction Process, Limitations, Comparison of Pressure and Liquid Storage.	9
Unit V	Principles of combustion: Chemistry and Stoichiometric calculation, Triangle theory, Combustion Equations, Thermodynamic analysis, Concept of adiabatic flame temperature. General Applications of Hydrogen. Fuel Cells (Principle, Characteristics, Types of Fuel Cells, Thermodynamics & Efficiency, Efficiency, System design). Hydrogen Economy.	9

References:

- 1) Hydrogen Energy by Bahman Zohuri, Springer Publications.
- 2) Fuels & Combustion by Sharma S.P. & Chander Mohan, Tata McGraw Hill Publishing Co. Ltd.
- 3) Hydrogen as Future Energy Carrier by Edited by Andreas Züttel, Andreas Borgschulte, and Louis Schlapbach, Wiley VCH Publications.
- 4) Fuels & Combustion by Sarkar Samir, Orient Longman.

SE-604: Waste to Energy

Type: PE

Course Objectives:

CO-1:	Understand the basic concepts of solid waste and disposal systems
CO-2:	Classify different techniques of waste treatment
CO-3:	Analyse the process of energy generation from different waste
CO-4:	Characterize the rural biomass usage and products/by-products of the process

CO-5:	Illustrate the various aspects of biomass combustion and processes involved

Syllabus

Units	Syllabus Details	Hrs
Unit I	Solid Waste -Definitions: Sources, types, compositions; Properties of Solid Waste; Municipal Solid Waste: Physical, chemical and biological property; Collection, transfer stations; Waste minimization and recycling of municipal waste. Landfill method of solid waste disposal; Landfill classification; Types, methods & siting consideration; Layout & preliminary design of landfills: Composition, characteristics, generation; Design of Sanitary Land fill - Movement and control of landfill leachate & gases; Environmental monitoring system for landfill gases. - Gas Recovery – Applications	9
Unit II	Waste Treatment & Disposal Size Reduction: incineration; Furnace type & design; Types of Incinerators – Fuel Economy - Medical /Pharmaceutical waste / Hazardous waste / Nuclear Waste incineration; Environmental impacts; Measures of mitigate environmental effects due to incineration.	8
Unit III	Energy Generation from Waste Types: Biochemical Conversion: Sources of energy generation, Industrial waste, agro residues; Anaerobic Digestion: Biogas production; Determination of BOD, DO, COD, TOC, & Organic loading, Aerobic & Anaerobic treatments – types of digester – factors affecting biodigestion - Activated sludge process. Methods of treatment and recovery from the in industrial waste water – Case Studies in sugar, distillery, dairy, pulp and paper mill, fertilizer, tanning, steel industry, textile, petroleum refining, chemical and power plant.	9
Unit IV	Rural applications of biomass –Combustion - Chulas - improved Chulas- Biomass – Physical - Chemical composition – properties of biomass – TGA – DSC characterization – Ash Characterization - Preparation of biomass – Size reduction – Briquetting of loose biomass-Briquetting machine	9
Unit V	Thermochemical Conversion -Basic aspects of biomass combustion - heat of combustion - different types of grates - Co combustion of biomass – Gasification - Fixed and Fluidized bed gasifier - Gasification technologies for the selected waste like Rice Husk, Coir pith, Bagasse, Poultry litter etc., - Pyrolysis	9

References:

1. Parker, Colin, & Roberts, Energy from Waste - An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985
2. Shah, Kanti L., Basics of Solid & Hazardous Waste Management Technology, Prentice Hall, 2000
3. Manoj Datta, Waste Disposal in Engineered Landfills, Narosa Publishing House, 1997
4. Rich, Gerald et.al., Hazardous Waste Management Technology, Podvan Publishers, 1987
5. Bhide AD., Sundaresan BB, Solid Waste Management in Developing Countries, INSDOC, New Delhi, 1983.

SE-605: Solar Energy Systems

Type: PSC-IV

Course Objectives:

CO-1 :	Understand the technical details of solar radiation
CO-2 :	Analyse different ways to utilize the solar energy
CO-3 :	Examine the ways solar energy proves beneficial in providing thermal comfort in buildings
CO-4 :	Identify the technical details of solar cells and their performance parameters
CO-5 :	Explain the applicability of solar photovoltaic systems and their operation

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Solar angles, day length, angle of incidence on tilted surface; Sunpath diagrams, Black body radiation, Analysis of Indian solar radiation data and applications, Selective Surfaces -Ideal coating characteristics; Types and applications; Anti-reflective coating;	9

Unit II	Concentrating Collector Designs - Classification, Compound parabolic concentrators; Parabolic trough concentrators; Concentrators with point focus; Heliostats; Comparison of various designs, Solar power plant; Solar furnaces - Vapour absorption refrigeration cycle; Water-ammonia & lithium bromide-water absorption refrigeration systems; Solar desiccant cooling. Solar still; Solar cooker; Solar pond.	8
Unit III	Solar Passive Building - Thermal comfort; Criteria and various parameters; Calculation of heating loads in buildings; Factors that effects energy use in buildings; Importance of Shading and Overhangs; Ventilation and its significance; Passive Cooling and Heating Concepts Direct heat gain, indirect heat gain, isolated gain and sunspaces; Passive cooling concepts: Evaporative cooling, radiative cooling; Application of wind, water and earth for cooling;	9
Unit IV	Solar Cell Physics –P-N junction: homo and hetro junctions, Upper limits on Cell parameters; Variation of efficiency with band-gap and temperature; Thin film solar cell technologies	9
Unit V	SPV Applications - Centralized and decentralized SPV systems; Stand alone, hybrid and grid connected system, Types of Solar panels	9

References:

1. Garg H P., Prakash J., Solar Energy: Fundamentals & Applications, Tata McGraw Hill, New Delhi, 1997
2. S P Sukhatme, Solar Energy, Tata McGraw Hill, 2008 11
3. J F Kreider and Frank Kreith, Solar Energy Handbook, McGraw Hill, 2000
4. D Y Goswami, Frank Kreith and J F Kreider, Principles of Solar Engineering, Taylor & Francis, 1998
5. Tiwari G.N., Suneja S., Solar Thermal Engineering System, Narosa Publishing House, New Delhi, 1997.

SE-606: Renewable Energy and Environmental Sustainability

Type: PE

Course Outcomes:

CO-1:	Understand the importance of environment in energy generation and consumption

CO-2:	Understand the social and economic impacts of actions in energy & environment
CO-3:	Analyse status and possibilities in rural electricity generation & utilization
CO-4:	Review the various energy & environment related policies from Government
CO-5:	Explain the applications of renewable energy technologies in rural areas

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Environmental sustainability- Definition and Importance, Sustainable Development Goals (SDGs), Energy Indicator Ratios-Economic, Social, and Environment dimensions, Traditional and modern energy use, Methods of accounting the role of traditional energy in the overall energy system.	9
Unit II	Integrated Rural Energy Planning (IREP): Origin, implementation, case studies, critique. Socioeconomic and environmental issues of traditional energy use. Health impacts of biomass burning in cookstoves.	8
Unit III	Rural electrification: Overview, current status and future perspectives. Linkages with rural livelihoods, rural industries and social development. Issues of subsidization, last mile access and paying capacity.	9
Unit IV	Review and critique of various programs of government: Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), Deen Dayal Upadhyay Gram Jyoti Yojna, SAUBHAGYA scheme, Principles, Advantages, limitations	9
Unit V	Use of efficient/appropriate/renewable energy technologies for rural areas. Technologies/products for cooking, water heating, drying, irrigation pumping, small/micro enterprises, lighting, motive power etc	9

References:

1. Report by a Panel of Experts, Rural electrification in Asia and the Far East New York United Nations, 1963,12
2. B. Kaye and William S: Pintz, Rural electrification issue papers Honolulu: Pacific Islands Development. 2004
3. Chambers, Ann, Distributed Generation: A Non-technical guide, 4th Ed., Penn well,

Oklahoma, 2001

4. Devadas, Planning for Rural Energy System: Part I & II, V Renewable and Sustainable Energy Reviews, 5 (2001), 203-226, 227-270. 5. T.C. Kandpal, H. P. Garg, Financial Evaluation of Renewable Energy Technology, Macmillan, New Delhi, 2003

PGC-601: Research Methodology and IPR

Type: Institute Level

Course Outcomes

CO-1:	Understand the meaning and characteristics of research problems
CO-2:	Learn how to conduct effective literature survey
CO-3:	Learn to write technical report and proposals
CO-4:	Understand about IPR, their importance, and new developments

Syllabus

Units	Syllabus Details	Hrs
Unit I	Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations.	9
Unit II	Effective literature studies approaches, analysis Plagiarism, Research ethics	7
Unit III	Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee.	8
Unit IV	Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation	8

	on Intellectual Property. Procedure for grants of patents, Patenting under PCT	
Unit V	Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.	7
Unit VI	New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies	7

References:

1. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for science & engineering students”
2. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
3. Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for beginners”
4. Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd, 2007.
5. Mayall, “Industrial Design”, McGraw Hill, 1992.

PGC-602: Audit I and II

Type: Institute Level

Unit I: English for Research Paper Writing

Unit II: Disaster Management

Unit II: Sanskrit for Technical Knowledge

Unit IV: Value Education

Unit V: Constitution of India

Unit VI: Pedagogy Studies

Unit VII: Stress Management by Yoga

Unit VIII: Personality Development through Life Enlightenment

SE-607: Wind and Hydro Energy Systems

Type: PSC-V

Course Outcomes:

CO-1:	Understand the technical details of wind energy conversion physics
CO-2:	Analyse the design and performance characteristics of wind turbines
CO-3:	Examine different hydropower systems
CO-4:	Illustrate the possibilities in hydro power generations and utilization
CO-5:	Explain the ocean thermal, geothermal, and thermo-electric energy systems

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Wind Energy Conversion - Wind energy conversion principles; General introduction; Types and classification of WECS; Power, torque and speed characteristics. Advantages – Limitations – Wind Rose Diagram – Wind Energy Conversion System - Design – Aerodynamic design principles; Aerodynamic theories; Axial momentum, blade element and combined theory; Rotor characteristics; Maximum power coefficient;	9
Unit II	Design of Wind Turbine - Wind turbine design considerations; Methodology; Wind Energy Application - Wind pumps: Performance analysis, design concept and testing; Principle of WEG; Stand alone, grid connected and hybrid applications of WECS; Economics of wind energy utilization; Wind energy in India	8
Unit III	Small Hydropower Systems - Overview of micro, mini and small hydro systems; Hydrology; Elements of pumps and turbine; Selection and design criteria of pumps and turbines; Site selection and civil works.	9
Unit IV	Speed and voltage regulation; Investment issues load management and tariff collection; Distribution and marketing issues: case studies; Potential of small hydro power in India. – SHP – Renovation and Modernization – Testing Methods.	9

Unit V	OTEC- Tidal Energy- Geothermal- MHD - Thermionic- Thermoelectric energy conversion system- Fuel Cells – Batteries – Micro Algae – Biodiesel from Algae.	9

References:

1. G L Johnson, Wind Energy Systems, Prentice Hall Inc, New Jersey, 1985.
2. David A. Spera, (Editor) Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering, American Society of Mechanical Engineers; (1994) 13
3. Erich Hau, Wind Turbines: Fundamentals, Technologies, Application and Economics, Springer Verlag; (2000)
4. Paul Gipe, Karen Perez, Wind Energy Basics: A Guide to Small and Micro Wind Systems, Chelsea Green Publishing Company; (1999)
5. J. F. Manwell, J. G. McGowan, A. L. Rogers, Wind Energy Explained, John Wiley & Sons; 1st edition (2002)

SE-608: Geothermal and Ocean Energy

Type: PSC-VI

Course Outcomes:

CO-1 :	Understand the basic concepts and technical details of geothermal energy system
CO-2 :	Analyse the functioning of a geothermal heat pump
CO-3 :	Illustrate the ocean thermal form of energy and possibilities associated with it

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Introduction of Geothermal Energy, Geothermal Recourses; definition and classification, Hydrothermal System, Hot dry rock system, Geopressured reservoirs, Magma Energy, utilisation of geothermal resources, Direct	19

	utilization; Measurement of rock density, thermal conductivity, specific heat, porosity, and permeability	
Unit II	Geothermal Power plants (GPPs)-principles and working, Organic Rankine Cycle, Kalina based GPPs, Geothermal heat pump- basic concepts, heating and cooling mode in heat pump, Heat pump with geothermal resources;	8
Unit III	Basics of Ocean Energy, currents, salinity, ocean floor characteristics; Forms of Ocean Energy- Wave energy, Tidal Energy, OTEC, and salinity gradient.	9
Unit IV	Ocean Thermal; Introduction, working principle, open, closed and hybrid cycle; Tidal energy devices-Tidal power generators, barrages, and lagoons. Wave energy devices- Wave profile device, Oscillating wave columns, wave energy converters, Reverse Electrodialysis, Pressure Retarded Osmosis.	

References:

1. Renewable Energy resources: basic principles and application by Tiwari and Ghosal.
2. Renewable Energy Sources by Boyle.

SE-609: Fuel and Combustion Technology

Type: PE

Course Outcomes:

CO-1:	Understand the characterization of different types of fuels
CO-2:	Perform classification of petroleum fuel, its products, and gaseous fuels
CO-3:	Understand and apply the basic principles in combustion and exhaust analysis
CO-4:	Illustrate the design concept in burner and associated modifications
CO-5:	Identify various types of furnaces used in energy industries and their performance

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Solid, Liquid and Gaseous Fuels - General: Coal; Family, origin, classification of coal; Analysis and properties; Action of heat on coal; Gasification; Oxidation; Hydrogenation and liquefaction of coal; Efficient use of solid fuels; Manufactured fuels; Agro fuels; Solid fuel handling; Properties related to combustion, handling, and storage.	9
Unit II	Origin and classification of petroleum; Refining; Properties & testing of petroleum products; Various petroleum products; Petroleum refining in India; Liquid fuels from other sources; Storage and handling of liquid fuels. Types of gaseous fuels: natural gases, methane from coal mines, manufactured gases, producer gas, water gas, biogas, refinery gas, LPG; Cleaning and purification of gaseous fuels.	8
Unit III	Theory of Combustion Process Stoichiometry and thermodynamics; Combustion stoichiometry: Combustion thermodynamics, burners; Fluidized bed combustion process. Stoichiometry relations; Estimation of air required for complete combustion; Estimation of minimum amount of air required for a fuel of known composition; Estimation of dry flue gases for known fuel composition; Calculation of the composition of fuel & excess air supplied, from exhaust gas analysis; Dew point of products; Flue gas analysis (O ₂ , CO ₂ , CO, NO _x , SO _x).	9
Unit IV	Burner Design Ignition: Concept, auto ignition, ignition temperature; Burners: Propagation, various methods of flame stabilization; Basic features and design of burners for solid, liquid, and gaseous fuels.	9
Unit V	Furnaces: Industrial furnaces, process furnaces, batch & continuous furnaces; Advantages of ceramic coating; Heat source; Distributions of heat source in furnaces; Blast furnace; Open hearth furnace, Kilns; Pot & crucible furnaces; Waste heat recovery in furnaces: Recuperators and regenerators; Furnace insulation; Furnace heat balance computations; Efficiency considerations.	9

References:

1. S.P. Sharma & Chander Mohan, Fuels & Combustion, Tata McGraw Hill Publishing Co.Ltd.,1984
2. J. D. Gilchrist , Fuels, Furnaces & Refractories, Pergamom Press, 1998
3. Blokh A.G, Heat Transmission in Steam Boiler furnaces, Hemisphere Publishing Corp.,1988

4. Gupta O.P, Elements of Fuels, Furnaces & Refractories, 3rd edition, Khanna Publishers, 1996.

5. Samir Sarkar, Fuels & Combustion, 2nd Edition, Orient Longman, 1990

SE-610: Integrated Energy Systems

Type: PE

Course Objectives:

CO-1:	Understand the need of storage and utilization principles of various energy forms
CO-2:	Interpret the technical details of magnetic and electrical energy systems
CO-3:	Analyse the different energy storage systems and their applications

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Energy Storage: Need of energy storage, Different modes of Energy Storage. Potential energy, Pumped hydro storage, KE and Compressed gas system, Flywheel storage, compressed air energy storage, Electrical and magnetic energy storage: Capacitors, electromagnets. Chemical Energy storage, Thermo-chemical, photo-chemical, bio-chemical, electro-chemical, fossil fuels and synthetic fuels, Hydrogen for energy storage, Solar Ponds for energy storage. Electrochemical Energy Storage Systems: Batteries: Primary, Secondary, Lithium, Solid-state and molten solvent batteries, Lead acid batteries, Nickel Cadmium Batteries, Advanced Batteries. Role of carbon nano-tubes in electrodes	9
Unit II	Magnetic and Electric Energy Storage Systems: Superconducting Magnet Energy Storage (SMES) systems, Capacitor and Batteries, Comparison and application, Super capacitor: Electrochemical Double Layer Capacitor (EDLC), principle of working, structure, performance and application, role of activated carbon and carbon nano-tube. Sensible Heat Storage: SHS mediums, Stratified storage systems, Rock-bed storage systems, Thermal storage in buildings, Earth storage, Energy storage in aquifers, Heat storage in SHS systems, Aquifers storage.	8

Unit III	Latent Heat Thermal Energy Storage: Phase Change Materials (PCMs), Selection criteria of PCMs, Stefan problem, Solar thermal LHTES systems, Energy conservation through LHTES systems, LHTES systems in refrigeration and air-conditioning systems, Enthalpy formulation, Numerical heat transfer in melting and freezing process.	9
Unit IV	Some Areas of Application of Energy Storage: Food preservation, Waste heat recovery, Solar energy storage, Green house heating, Power plant applications, Drying and heating for process industries.	9

References:

1. Garg H P., Prakash J., Solar Energy: Fundamentals & Applications, Tata McGraw Hill, New Delhi, 1997
2. S P Sukhatme, Solar Energy, Tata McGraw Hill, 2008
3. J F Kreider and Frank Kreith, Solar Energy Handbook, McGraw Hill, 2000
4. D Y Goswami, Frank Kreith and J F Kreider, Principles of Solar Engineering, Taylor & Francis, 1998
5. Tiwari G.N., Suneja S., Solar Thermal Engineering System, Narosa Publishing House, New Delhi, 1997.

SE-611: Rural Electrification Technologies

Type: PE

Course Outcomes:

CO-1:	Understand the basic concepts of technologies for rural electrification
CO-2:	Interpret the technical details of electrification process
CO-3:	Classify the different turbine generator and their usage
CO-4:	Illustrate the concepts and current status of biomass based electricity generation

CO-5:	Identify the technical and economic details of power grid.

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Decentralized generation technologies; Costs and choice of technology, Demand and benefits forecasting and program development, Principles of cost-benefit calculations	9
Unit II	Economic and financial analysis of stand-alone electrification projects, Decentralized versus central station generation, Traditional power systems, Load curves and load curve analysis	8
Unit III	Basic gas turbine generator concepts; Utility system turbine generators; Mini and micro gas turbine generators; Solar thermal power generation, utility scale photovoltaic (USPV) generation; Wind-powered generation.	9
Unit IV	Biomass based generation; DG Evaluation: Cost from past, present, and future, basic DG cost analysis, cost Evaluation and schedule of demand.	7
Unit V	The power grid; DG-Grid interconnection issues, Mini and Micro Grids – Economics– Environmental Factors – Transmission and Regulations	7

References:

1. H. Lee Willis and W.G. Scott: Distributed Power Generation: Planning and Evaluation, Marcel Dekker, 2000.
2. J. J. Burke: Power Distribution Engineering, Fundamentals and Applications, Marcel Dekker, 1994.
3. T. Gonen: Electric Power Distribution System Engineering, McGraw-Hill 1986.
4. M Mohan: Rural electrification for development: policy analysis and applications. Boulder: Westview Press, 1987
5. G. Saunier: Rural electrification guidebook for Asia and the Pacific, Asian Institute of Technology, 1992.

SE-612: Energy Storage and Transport Systems

Type: PE

Course Outcomes:

CO-1:	Understand the requirement and different ways of energy storage
CO-2:	Identify the different technologies and parameters related to energy storage
CO-3:	Illustrate the design and application areas of energy storage and modern energy solutions

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Introduction: Necessity of energy storage, different types of energy storage, mechanical, chemical, electrical, electrochemical, biological, magnetic, electromagnetic, thermal, comparison of energy storage technologies Energy Storage Systems: Thermal Energy storage, sensible and latent heat, phase change materials, Energy and exergy analysis of thermal energy storage	11
Unit II	Electrical Energy storage-super-capacitors, Magnetic Energy storage-Superconducting systems, Mechanical-Pumped hydro, flywheels and pressurized air energy storage, Chemical-Hydrogen production and storage, Principle of direct energy conversion using fuel cells, thermodynamics of fuel cells, Types of fuel cells, AFC, PEMFC, MCFC, SOFC, Microbial fuel cell, Fuel cell performance, Electrochemical Energy Storage- Battery, primary, secondary and flow batteries	12
Unit III	Design and Applications of Energy Storage: Renewable energy storage-Battery sizing and stand-alone applications, stationary (Power Grid application), Small scale application-Portable storage systems and medical devices, Mobile storage Applications- Electric vehicles (EVs), types of EVs, batteries and fuel cells, future technologies, hybrid systems for energy storage.	12

References:

1. Energy Storage - Technologies and Applications by Ahmed Faheem Zobaa, InTech.
2. Fundamentals of Energy Storage by J. Jensen and B. Sorenson, Wiley-Interscience, New York,
3. Handbook of battery materials by C. Daniel, J. O. Besenhard, Wiley VCH Verlag GmbH & Co. KGaA

4. Electric & Hybrid Vehicles by G. Pistoia, Elsevier B. V.
5. Thermal energy storage: Systems and Applications by Dincer I. and Rosen M. A., Wiley pub.

SE-613: Energy Auditing and Management

Type: PE

Course Outcomes:

CO-1 :	Understand the basics of energy and principles of its conservation and management
CO-2 :	Analyse and understand different technical terms in energy audit
CO-3 :	Classify different furnace types, boilers, and performance parameters
CO-4 :	Illustrate different electric motor types and technical details of their operation
CO-5 :	Understand and interpret various environment concerns and various guidelines

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Basics of energy & its various forms: Electricity basics, electricity tariff, load management and maximum demand control, power factor. Thermal basics – fuels, thermal energy content of fuels, temperature and pressure, heat capacity, sensible & latent heat, evaporation, condensation, steam, moist air, humidity and heat transfer, units and conversion. -Energy Conservation Act-2001 and its Features.	9
Unit II	Energy management and audit: Definition, energy audit – need, types of energy audit, energy management (audit) approach – understanding energy costs, benchmarking, energy performance Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments	8
Unit III	Boilers: Types, combustion in boilers, performance evaluation, analysis of losses, Energy conservation opportunities. Furnaces: Classification, general	8

	fuel economy measures in furnaces, excess air, heat distribution, waste heat recovery.	
Unit IV	Electric motors: Types, Losses in induction motors, Motor efficiency, Factors affecting motor performance, Rewinding and motor replacement issues, Energy saving opportunities with energy efficient motors. Energy Efficient Technologies in Electrical Systems: Energy efficient motors, Soft starters with energy saver, Variable speed drives, Energy efficient transformers.	9
Unit V	Global environmental concerns: United nations framework convention on climate change (UNFCCC), Kyoto protocol, conference of parties (COP), clean development mechanism (CDM), prototype carbon fund (PCF), sustainable development	7

References:

1. CB Smith, Energy Management Principles, Pergamon Press, NewYork, 1981
2. Hamies, Energy Auditing and Conservation; Methods, Measurements, Management & Case study, Hemisphere, Washington, 1980
3. D Patrick and S W Fardo, Energy Management and Conservation, Prentice Hall Inc., 1996
4. Thuman A and Mehta D Paul, Handbook of Energy Engineering, The Fairmount Press., 1998
5. Kennedy, Turner and Capehart, Guide to Energy Management, The Fairmount Press., 1996

SE-614: Energy Modelling and Simulation

Type: PE

Course Outcomes:

CO-1 :	Understand the basics concepts in economics of energy
CO-2 :	Interpret the energy and environment system analysis
CO-3 :	Understand the methodology to perform energy demand modelling, forecasting
CO-4 :	Illustrate the economics of different energy forms and their conservartion

CO-5 :	Perform the cost analysis for project evaluation

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Unit I- Macroeconomic Concepts - Economics of Energy Sources - Reserves and Cost Estimation, Multiplier Analysis - Energy and Environmental Input / Output Analysis	8
Unit II	Unit II- Energy Demand Modelling - Overview of Econometric Methods. Energy Forecasting Fundamentals - Energy time series data, Trend and Seasonality, forecasting of energy demand – Exponential Smoothing and Holt's method	8
Unit III	Unit III- Introduction to design and simulation, system definition, techniques of system simulation, regression analysis, solution to linear & non-linear algebraic equations, successive substitution, Newton-raphson method, applications to energy systems simulations.	9
Unit IV	Unit IV- Fundamentals of Optimization: unimodal, multi-modal functions, objective function, maxima and minima, Constrained and unconstrained optimization- Method of Lagrange multipliers, Kuhn-Tucker conditions, application of optimization to energy systems	8
Unit V	Unit V- Environmental Impact Assessment (EIA)- Basic concepts, origin, and principles, EIA stages	7

References:

1. M.Munasinghe and P.Meier Energy Policy Analysis and Modeling, Cambridge University Press 1993
2. W.A.Donnelly The Econometrics of Energy Demand: A Survey of Applications, New York.1987
3. S.Pindyck and Daniel L.Rubinfeld Econometrics Models and Economic Forecasts, 3rd edition MC Graw -Hill, New York 1990
4. UN-ESCAP Sectoral Energy Demand Studies: Application of the END-USE Approach to Asian Countries, New York 1991

5. UN-ESCAP Guide Book on Energy -Environment Planning in Developing Countries: Methodological Guide on Economic Sustainability and Environmental Betterment Through Energy Savings and Fuel Switching in Developing Countries, New York 1996

SE-615: Smart Grid

Type: PE

Course Outcomes:

CO-1 :	Understand the basic concepts and current status of smart grids in India
CO-2 :	Identify different communication network and technical details
CO-3 :	Analyse the use of power electronics in smart grid systems
CO-4 :	Illustrate technologies for improvement of smart grid systems
CO-5 :	Explain the challenges and possibilities in transmission systems

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Introduction –driving the move towards Smart Grids globally and in India Smart Grid. Overview of how Indian power market is organized, operated and challenges being faced. Overview of how the Indian GENERATION, TRANSMISSION and DISTRIBUTION business is operated and controlled and some of the challenges being faced. How software can manage generation and optimize generator performance, Software to support integration of renewables, System planning & condition monitoring based maintenance, Forecasting & basic trading, Demand response, Performance management.	9
Unit II	Overview of power sector communications, Generic model of communication network needed for Smart-grid, Introduction to different communication technologies available in the market (Latest standards, emphasis on importance of interoperability and standardization of communication protocols), Matrix of different technologies against the smart-grid communication needs in a given utility environment, AMI, AMR & MDA: How it works and how it will help to; reduce peaks manage networks more efficiently and contribute towards smarter grids,	8

	Communication Standards IEC6150, Wide Area Situation Awareness (WASA), Network stability and Phasor Measurement Unit (PMU), 6Automation and Integration of Distributed Generation / Renewable Energy, Automation and Micro-grids	
Unit III	Distribution Management Systems (DMS) and Meter Data Management (MDM) are improving energy efficiency and security of supply in Distribution Systems, Overview of Power Electronics in Electrical T&D Systems, Power Electronics in emerging Smart Grids, Transmission (DC Super Grids) , Distribution (PE facilitating the integration of, (Distributed Generation, Renewables, Microgrids, Virtual Power Plants (VPP), Storage, Fault Current Limitation, Power Electronics, Super Conducting and Magnetic types id.	9
Unit IV	Developing technology and systems that will enable grids to work smarter in the future: Storage: Organic and Inorganic Salts & Synthetic Heat Storage, Developing technology and systems that will enable grids to work smarter in the future (Smart Meters, Recording consumption, Advanced payback options for load-management, Communication between the utility and customer's home (for home automation)), In-home controls, Demand Side Management (DSM).Power Trading & the India Energy Exchange : Encouraging Markets, Regulation enabling grids to work smarter in India, Project Financing: Financial Incentives to Enable Smart Grids in India, Smart Grid Economics: Making Smarter Grids Financially Viable, Planning for Smarter Grids	9
Unit V	Challenges faced by the Transmission System Developing technology and systems that will enable smarter transmission of bulk energy (Metering, Trading mechanisms, AC – FACTS (Statcom). DC – HVDC, Fault Current Limiters), Challenges faced by the Distribution Networks:(How to be more energy efficient, stable, reliable and environmentally friendly, Reducing losses, Integration of renewables connecting/disconnecting micro-grids and virtual power plants, manage bi-directional energy flows), Developing technology and systems that will enable smarter distribution networks (DC – MVDC, Fault Current Limiters, Others (AC/DC TXs etc)).	7

References:

1. Join Gridwise & Smartgrids groups in LinkedIn <http://www.linkedin.com/>
2. Sign up to Smart Grid News www.smartgridnews.com
3. USDoE Smart Grid Book
[http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages\(1\).pdf](http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages(1).pdf)

4. Technology enabling the transformation of India's power distribution

<http://www.infosys.com/newsroom/features/power-sector-report.pdf>

5. Gridwise Alliance website <http://www.gridwise.org/>

SE-616L: Renewable Energy Laboratory

Type: PSL-I

Course outcomes:

CO-1 :	Understand the application of solar energy and utilisation
CO-2 :	Understand the application of wind energy and utilisation
CO-3 :	Analyse the biomass systems
CO-4 :	Understand the formation of bio-gas system
CO-5 :	Explain the challenges and advances in Renewable Energy

List of Experiments

1. Study of various hydrocarbon fuels and its properties.
2. To study energy auditing related to thermal and electrical utilities.
3. Study of waste heat recovery devices and cogeneration.
4. Experiment to synthesize / produce biodiesel by Trans-esterification process of edible oil.
5. Experiment to synthesize / produce biodiesel by Trans-esterification process of non-edible oil.
6. To study production of alcohol from biomass.
7. Experiment to identify functional group in bio-fuel through FTIR.
8. Experiment to find mixture contents in a bio-fuel through GCMC.
9. Production of hydrocarbon fuel through continuous hydrogenation (Reaction purpose).

10. Study of Bio gas plant.
11. Experiment to produce hydrogen through Biomass Gasifier.
12. Study of operation of Spark Ignition Engine in two-wheeler vehicle.
13. Study of operation of Compression Ignition Engine in four-wheeler vehicle.
14. To study various methods of production, storage, transportation, and distribution of hydrogen.
15. To calculate heating value/calorific value of Bio-fuel using Bomb Calorie meter.
16. To find density and specific gravity Bio-fuel through density meter.

SE-617L: Renewable Energy Laboratory II

Type: PSL-II

Course outcomes:

CO-1 :	Understand the qualitative analysis of Coal
CO-2 :	Understand the Energy Content and Utility of Fuels
CO-3 :	Analyse the Solid Waste Management
CO-4 :	Understand the Liquid Waste Management
CO-5 :	Explain the challenges and advances in Renewable Energy

List of Experiments

1. To find viscosity of Bio-fuel by viscometer.
2. To find flame speed of hydrogen fuel by high pressure reactor.
3. To perform the distillation of Bio-fuel synthesized in lab.
4. To measure and study regulated emission through 5 gas analyzers.
5. To study Photo chemical Reactor and its applications.
6. Study of vacuum Rotary evaporator.
7. Detailed Study of Solar Simulator facility.
8. Study of cross flow heat exchanges of and calculation of surface heat transfer coefficient.
9. Experiment to study of Solar Power Module: Get different voltage & current, comprehend characteristic curve of I/V, V/P and MPP and learn solar power module.

10. Experiment to find output transduction DC TO AC INVERTER Module for understanding of output transduction.
11. Experiment for regeneration use of solar power through Charging Module Battery charging control function like VBAT (Charging Voltage), IBAT (Charging Current) and VMPP (Maximum Power Point).
12. Study of Thermal imaging camera.
13. Study of Flat plate collectors.
14. To study Waste Water Treatment by reverse osmosis setup.
15. To study the TGA-DSC characterization of glycerol waste generated during bio-fuel synthesis.
16. To find the C, H, M, S composition of bio-fuel through elemental analyzer.

SE-628: Battery and Fuel Cell Technology

Type: PE

Course Outcomes:

CO-1 :	Understand the basic concepts and current status of fuel cell technology
CO-2 :	Identify different parts and thermos-chemistry of fuel cell
CO-3 :	Analyse the chemical kinetics of fuel cell
CO-4 :	Understand the characterization of fuel cell
CO-5 :	Explain the challenges and advances in fuel cell technology

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Introduction and overview of fuel cell – requirement, history, principle, overview and basic electrochemistry of the fuel cell. Thermodynamics of Fuel Cell- Gibb's free energy, reversible and irreversible losses, fuel cell efficiency,	9
Unit II	Nernst equation: Effect of temperature, pressure and concentration on Nernst potential, Concept of Electrochemical Potential Components of Fuel cell: Electrolyte, catalyst, bipolar plate/current collector	8

Unit III	Activation Polarization-electrochemical kinetics, reaction rate, surface coverage, Activation polarization for charge transfer reaction, Butler-Volmer equation, Tafel equation.	8
Unit IV	Concentration Polarization: Diffusion transport in electrodes, transport through flow channel, concentration polarization, Ohmic polarization: Ionic conductivity and Electronic Conductivity Fuel Cell Characterization: Possible ways of Characterization, IV characteristics and electrochemical impedance spectroscopy, cyclic voltammetry	9
Unit V	Comparison of High temperature and low temperature fuel cell, Different types of fuel cell Hydrogen production and storage, safety issues and Cost issues Advances in solid oxide fuel cells	8

References:

1. O'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals, Wiley, N.Y
2. Bard, A. J., L. R., Faulkner, Electrochemical Methods, Wiley, N.Y
3. Basu, S. (Ed) Fuel Cell Science and Technology, Springer, N.Y.
3. Liu, H., Principles of fuel cells, Taylor & Francis, N.Y
4. Electrochemistry of cleaner environments, J OM Bockris, Springer, US

SE-632: Energy Efficient Materials

Type: PE

Course Outcomes:

CO-1 :	Understand the basic concepts alternative material
CO-2 :	Understand and analyse solar photovoltaic system
CO-3 :	Analyse the fuel cell technology
CO-4 :	Illustrate technologies like thermoelectrics and energy harvesting

CO-5 :	Explain the potential of nuclear based materials

Syllabus:

Units	Syllabus Details	Hrs
Unit I	Need of Alternative materials, Green Materials, Biomaterials, Natural and synthetic Polymers.	5
Unit II	Photovoltaic (PV) thin films for solar cells; Organic Solar Cells; dye sensitized solar cells; Thermo photovoltaic (TPV) devices.	5
Unit III	Fuel cells, the role of the fuel in the operation, performance and degradation of fuel cells; Membrane electrode assemblies for polymer electrolyte membrane fuel cells;	8
Unit IV	Developments in membranes, catalysts and novel cathode and anode materials; Membranes, adsorbent materials and solvent-based materials for syngas and hydrogen production fuel cells, Batteries, Ultra capacitor; Super capacitors. Thermoelectrics, Novel illumination sources for efficient lighting, Energy saving in buildings.	10
Unit V	Materials and techniques for energy harvesting; Lithium batteries: Current technologies and future trends. Thermoelectric materials for conversion of heat to electricity. Materials issues for future nuclear energy; Radiation damage, recovery mechanisms, and creep-rupture, modelling and theoretical aspects	10

References:

1. Materials for Renewable and Sustainable Energy (Springer).

SE-633: Safety, Health & Hazard Management

Type: PE

Course Outcomes:

CO-1:	Understand the classification of hazardous materials

CO-2:	To learn the basics of Hazop and Hazan techniques
CO-3:	Identify different types of hazards and analyze their prevention measures
CO-4:	Study the hazards of chemical, biological and nuclear explosives
CO-5:	Evaluate the various levels of safety protocols

Syllabus

Units	Syllabus Details	Hrs
Unit I	Chemical Safety: Standards and regulations of chemical safety in Industries or Laboratories, Storage of hazardous chemicals, Compatibility and classification codes, Chemical risk analysis and management, Fire triangle and Handling of Toxic, Industrial Gases.	9
Unit II	Hazard Management: HAZOP and HAZAN techniques, Hazard in manufacture, Hazard prevention measures, Disposal of hazardous materials.	8
Unit III	Warfare: Classifications of explosives based on hazards, Nuclear, biological and chemical warfare safety.	9
Unit IV	Health: Assessment of human factors, Health & Environment safety, Nano materials safety (Toxicology study) TUTORIALS/ PRACTICALS/ SEMINARS: Handling & demonstration of air-sensitive, pyrophoric and toxic chemicals Monitoring of effluents through Gas Chromatography/Ion Chromatography	9
Unit V	Personal Protection	9
Unit VI	MSDS for known/ unknown compounds.	8

References:

1. Safety of reactive chemicals and pyrotechnics by Tadao Yoshida, et al.
2. Chemistry of hazardous materials by Eugene Meyer.
3. Hazardous and toxic materials (safe handling and disposal) by Fawcett.
4. Safety and accident prevention in chemical operations John Wiley and sons, New York, 1982.

5. Technical guidance for hazard analysis USEPA, FEMA, USDOT, 1987 Nanotechnology Environmental Health and Safety: Risks, Regulation and Management.
6. Nanotechnology Environmental Health and Safety: Risks, Regulation and Management M. Hull, D. Bowman, Elsevier, 2010.
7. Manual on emergency preparedness for chemical hazard, Ministry of Environment and Forest, Govt. of India, New Delhi, 1989.

*Department of
Metallurgical &
Materials Engineering*

M.Tech. in Materials Engineering

Course Syllabus

SEMESTER I

S.No.	Course Type	Course Code	Course Name	Contact Hours		Credits
				L	T/P	
1	PSC-1	MM 601	Concepts in Metals and Ceramics	3	0	3
2	PSC-2	MM 602	Materials Characterization	3	0	3
3	PSC-3	MM 603	Thermodynamics of Materials	3	0	3
4	PSC-4	MM 604	Physical Metallurgy	3	0	3
5	PE-1	E1	Elective I	3	0	3
6	PSL/PSC/PE	MM 601L	Materials Preparation and Characterization Laboratory-I	0	6	3
7	PGC	PGC-601	Research Methodology and IPR	2	0	2
			Total			20

PSC: Program Specific Core

PSL: Program Specific Lab

PE: Professional Elective

PGC: Post-Graduate Committee

SEMESTER II

S.No.	Course Type	Course Code	Course Name	Contact Hours/week		Credits
				L	T/P	
1	PSC-5	MM 605	Mechanical Behavior of Materials	3	0	3
2	PSC-6	MM 606	Materials Processing	3	0	3
3	PE-II		Elective II (Open Elective)	3	0	3
4	PE-III		Elective III (Open Elective)	3	0	3
5	PE-IV		Elective – IV (Open Elective)	3	0	3

6		MM 602L	Materials Processing and Testing Laboratory-II	0	6	3
7		PGC-602	Communication Skills and Personality Development	2	0	2
			Total			20

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	MM-651	M.Tech. Dissertation Phase I	40		20
		Total			20

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	MM-652	M.Tech. Dissertation Phase II	40		20
		Total			20

List of Electives:

Sr. No.	Course Code	Electives from the Department
1	MM 607	Concepts of Polymers and Composites
2	MM 608	Mathematics for Computational Materials Engineering
3	MM 609	Fatigue, Fracture, and Failure Analysis
4	MM 610	Introduction to Computational Materials Engineering
5	MM 611	Nanomaterials and Their Applications
6	MM 612	Non-Destructive Evaluations
7	MM 613	Polymer Blends and Nanocomposites
8	MM 614	Biomaterials
9	MM 615	Design of Materials
10	MM 616	Magnetism and Magnetic Materials

11	MM 617	Heat-treatment of Metals and Alloys
12	MM 618	Materials for High-Temperature Applications
13	MM 619	Advanced Steel Technology
14	MM 620	Military Materials
15	MM 621	Introduction to Corrosion
16	MM 622	Welding Science and Technology
17	MM 623	Corrosion in Hostile Environments
18	MM 624	Corrosion Mitigation
19	MM 625	Composite Materials
20	MM 626	Advanced Coating
21	MM 627	Surface Science and Engineering
22	MM 628	Reliability Engineering

Program Outcomes (POs)

- **PO1:** An ability to independently carry out research /investigation and development work to solve practical problems
- **PO2:** An ability to write and present a substantial technical report/document
- **PO3:** Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program

Program Specific Outcomes (PSOs)

On completion of M.Tech (Materials Engineering) programme graduates will be able to

- **PSO1:** To analyse and tackle the complex and diverse engineering problems by appropriate experimentation and interpretation, and, provide probable solutions by applying principles of Materials engineering in combination to the fundamental knowledge of basic sciences.
- **PSO2:** To be able to design and device new procedures to arrive at a solution for identifying or troubleshooting problems at fundamental/system/component level.
- **PSO3:** An ability to work together collaboratively in multidisciplinary teams to tackle multifaceted problems and pursue a bright career in Materials engineering and allied areas by demonstrating professional success at different platforms within industry, governmental bodies such as Defence Research and Development Organization & Tri -services (Army, Navy & Air force), Coast Guard, DGQA, DQA, and Defence Public Sector units.

➤ **Core Courses:**

Course Code	Course Name	L – T – P	Credits
MM 601	Concepts in Metals and Ceramics	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Provide foundational knowledge of material classification and atomic-level structures • Distinguish between crystalline and non-crystalline materials • Explore the properties, classification, structure, and defects of ceramic materials • Analyze the behavior and properties of dielectric materials and refractories • Understand the structure, types, and applications of glass materials			
Course Contents Unit I: Introduction, classification of materials; atomic structure, bonding in solids, bonding forces and energies; crystal structure, unit cells, crystal systems, crystallographic points, directions, and planes. Unit II: Crystalline and non-crystalline materials, anisotropy; Structure of crystalline solids: metallic crystal structure. Unit III: Ceramic materials, Basic properties, classification of ceramic materials—conventional and advanced, ceramic crystal structure, Defects in ceramics: types of defects, origin of point defects, defects and electron energy levels, defect equilibria in ceramic crystals, Phase equilibria in ceramics, Industrial applications of ceramics and ceramic coatings, mechanical properties of ceramics. Unit IV: Dielectrics: Dielectric strength, Loss factor. Equivalent circuit description of linear dielectrics, Power factor, Dielectric polarisation, Polarisation mechanisms, Applications. Refractories: Classification of Refractories, Applications. Unit V: Glass: Definition of glass, Basic concepts of glass structure, Different types of glasses. Application of glasses.			
Course Outcomes After completing this course, the students will be able to: CO1: Understanding classifications and characteristics of materials CO2: Analysis and properties of crystalline materials CO3: Detailed overview of ceramics and their characteristics CO4: Cognizance of dielectrics, refractories, and their applications CO5: Basic knowledge of glass and glass ceramics and their applications			
Text Books • Materials Science and Engineering by William D. Callister, John Wiley & Sons, Inc. • Elements of Materials Science and Engineering by Lawrence H. van Vlack.			
Reference Books • Elements of Ceramics: F. H Norton • Fundamentals of Ceramics: Barsoum • Introduction to Ceramics: W.D. Kingery • Physical Ceramics for Engineers: VanVlack • Handbook of Ceramics: Editor S. Kumar Ceramic • Materials for Electronics: R.C. Buchanon			

Course Code	Course Name	L – T – P	Credits
MM 602	Materials Characterization	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamental principles of microscopy and imaging techniques • Develop a thorough understanding of diffraction techniques • Explain the principles and applications of spectroscopic techniques • Provide knowledge of UV-visible and vibrational spectroscopy • Familiarize students with thermal analysis techniques			
Course Contents Unit I Microscopy and Imaging- Fundamentals of Imaging: magnification, resolution, depth of field and depth of focus, aberration and astigmatism, SEM: imaging modes, image contrast, illustrative applications, Basic principle and components of TEM: Contrast mechanisms, bright field, dark field, TEM application in crystal defect analysis, Electro diffraction in TEM. Unit II Diffraction Techniques- Concepts of diffraction, scattering, and radiation-matter interactions, X-ray diffraction, structure factor determination, phase identification, strain, and crystallite size determination. Unit III Spectroscopic Techniques- Basis of Spectroscopic analysis, EDS, and WDS applications, X-ray Photoelectron Spectroscopy and Auger electron spectroscopy, EBSD principles and applications Unit IV UV-visible spectroscopy- Beer's law, Instrumentation, Quantitative analysis; Vibrational spectroscopy- Raman and Infrared, Principles of vibrational spectroscopy, Infrared and Raman activity, Fourier transform infrared spectroscopy, Instrumentation, Applications Unit V Thermo gravimetric analysis (TGA), Differential thermal analysis (DTA), Differential scanning calorimetry (DSC), Dynamic mechanical analysis (DMA), Thermomechanical analysis (TMA): Basic theory, Instrumentation, and applications.			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Understanding the diffraction techniques and their role in crystal structure determination CO-2: Knowledge of microscopic terminologies, basic concepts, capabilities, and their applications CO-3: Cognizance of basic principles of spectroscopic techniques, capabilities, and their applications CO-4: Understanding of thermal analysis techniques			
Text Books			
• <i>Materials Characterization: Introduction to Microscopic and Spectroscopic Methods</i>, Y. Leng, John Wiley & Sons (Asia), 2008. • <i>Materials Characterization Techniques</i>, S. Zhang, Lin Li, A. Kumar, CRC Press, 2008. • <i>Elements of X-ray Diffraction</i>, B. D. Cullity, Prentice Hall, 2001 • <i>Solid State Chemistry and its Applications</i>, Anthony R. West, Wiley.			
Reference Books			
• <i>Materials Characterization, ASM Handbook Vol 10.</i> • <i>Characterization of Materials, Vol I</i>, Elton N. Kaufmann			

Course Code	Course Name	L – T – P	Credits
MM 603	Thermodynamics of Materials	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand the fundamental concepts of thermodynamic systems and processes - Explore reversible and irreversible processes - Introduce and apply auxiliary thermodynamic functions - Explain the statistical basis of thermodynamics - Analyze free energy behavior in single-component systems			
Course Contents Unit I Simple and composite systems, phases, Internal energy, Enthalpy, Entropy, Gibbs Free energy, Specific heat, Laws of thermodynamics, Reversible and Irreversible processes, adiabatic work interaction. Unit II Generation of Auxiliary Functions: Legendre transforms, Coefficient relations, Maxwell's relations, Thermodynamic relations among state functions variables and its application to solids Unit III Statistical definition of temperature and entropy, Micro- and Macro-states, Maxwell-Boltzmann distribution, Thermodynamic equilibrium: stable equilibrium states, criteria for equilibrium Unit IV Free energy of single component system: Free energy as a function of temperature, Clausius-Clapeyron Equation, Driving force for solidification; Equilibrium vacancy concentration and Analysis of Magnetic transitions			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Understand the basic principles of thermodynamic concepts CO-2: Learn the thermodynamic relations among variables and their transformations CO-3: Demonstrate basics of statistical thermodynamics CO-4: Analysing free energy equation and curves and its interpretation for single component system CO-5: Detailed understanding of binary system, phases formation and chemical potential			
Text Books			
- David R. Gaskell, <i>Introduction to the Thermodynamics of Materials</i>, Taylor & Francis, 1798 - Ahindra Ghosh, <i>Textbook of Materials and Metallurgical Thermodynamics</i>. Prentice Hall of INDIA 2003			
Reference Books			
- R.T. DeHoff, <i>Thermodynamics in Materials Science</i>, McGraw-Hill, Singapore, 1993 D. A. Porter and K. E. Easterling, <i>Phase transformations in Metals and Alloys</i>, Chapman and Hall, London, 1996 - Taiji Nishizawa, <i>Thermodynamics of microstructures</i>, ASM International			

Course Code	Course Name	L – T – P	Credits
MM 604	Physical Metallurgy	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand the principles of diffusion in solids - Analyze the processes involved in solidification and phase transformations - Interpret phase diagrams and apply phase rule concepts - Study time-temperature-transformation (TTT) and continuous-cooling-transformation (CCT) diagrams			

Explore various deformation and strengthening mechanisms in materials
Course Contents Unit I Diffusion in ideal, nonideal, substitutional and interstitial solid solutions, The Kirkendall effect, Darken's equations, Fick's First law, Fick's second law, Self diffusion in pure metals, temperature dependence of diffusion coefficient, diffusion along grain boundaries and free surfaces. Unit II Solidification of metals, crystal growth from the liquid phase, dendritic growth, segregation, solid state transformation, homogeneous nucleation, heterogeneous nucleation, growth kinetics, diffusional controlled growth, interface-controlled growth. Unit III Phase rule, Phase diagram, Isomorphous alloy systems, The lever rule, Equilibrium heating and cooling of an isomorphous alloy, Microstructure, Thermodynamics of solutions, Phase equilibrium in single and multi-phase systems. Eutectic, Fe-FeC diagram. Miscibility gaps. Unit IV TTT and CCT diagrams for carbon steel, Heat treatment of steels, and light alloys. Pearlitic, Bainitic and Martensitic transformations. Unit V Deformation and Strengthening mechanisms: Solid solution strengthening, strengthening from grain boundaries, strain hardening, strengthening from particles, precipitation hardening.
Course Outcomes After completing this course, the students will be able to: CO-1: To understand diffusion in metals and alloys CO-2: To learn liquid and solid-state transformation in metals CO-3: To know metallurgy of steel and light alloys CO-4: To learn various heat treatments of steel and light alloys CO-5: Conception of several deformation and strengthening mechanisms
Text Books <i>Physical Metallurgy Principles, Robert E Reed-Hill, EWP Pvt, Ltd, 2019</i>
Reference Books <i>Mechanical Metallurgy, G.E. Dieter, McGraw-Hill book company, 1988</i> <i>Mechanical behaviour of Materials, Williams F Hosford, Cambridge University press, 2005</i> <i>Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.</i>

Course Code	Course Name	L – T – P	Credits
MM 601L	Materials Preparation and Characterization Laboratory-I	0-0-6	3
Course Objectives: The primary objectives of this course are to: - Develop proficiency in sample preparation and microstructural analysis techniques - Gain hands-on experience in material characterization methods - Understand and perform various material and nanomaterial synthesis techniques			
Course Contents - Metal polishing and microstructure analysis - Sample preparation and imaging using scanning electron microscopy and interpretation - X-ray diffraction characterization and crystal structure determination - Material synthesis by the solid-state method - Nanomaterial synthesis by the hydrothermal method - Nanomaterial synthesis by the co-precipitation process			

7	Material synthesis by the Sol-Gel technique
Course Outcomes	
After completing this course, the students will be able to:	
CO-1 Learn hands-on practical of metallic sample preparation	
CO-2 Perform and learn morphological characterization by XRD and microscopy	
CO-3 Perform and learn nanomaterials synthesis by various methods	
Text Books	
Reference Books	

Course Code	Course Name	L – T – P	Credits
PGC-601	Research Methodology and IPR	2-0-0	2
Course Objectives: The primary objectives of this course are to: • Understand the fundamentals of research methodology • Develop skills for conducting effective literature reviews • Enhance technical writing and communication skills • Gain foundational knowledge of Intellectual Property Rights (IPR) • Explore advanced concepts and current developments in IPR			
Course Contents Unit I: Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations Unit II: Effective literature studies approaches, analysis Plagiarism, Research ethics, Unit III Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee Unit IV Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. Unit V Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications Unit VI New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional Knowledge Case Studies, IPR and IITs.			
Course Outcomes			
After completing this course, the students will be able to:			
CO-1 Understanding the fundamentals of research and its methodology			
CO-2 Choose the appropriate research design and develop appropriate research hypothesis for a research project			
CO-3 Knowledge of manuscript preparation, patents and Intellectual property			

CO-4 Technology transfer and application of IPR in various domains
Text Books
Reference Books
• <i>Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students"</i> • <i>Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"</i> • <i>Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"</i> • <i>Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd, 2007.</i> • <i>Mayall, "Industrial Design", McGraw Hill, 1992.</i> • <i>Niebel, "Product Design", McGraw Hill, 1974.</i> • <i>Asimov, "Introduction to Design", Prentice Hall, 1962.</i> • <i>Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.</i> • <i>T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008</i>

Course Code	Course Name	L – T – P	Credits
MM 605	Mechanical Behavior of Materials	3-0-0	2
Course Objectives: The primary objectives of this course are to: • Understand the fundamentals of elasticity and stress analysis • Explore the principles of plastic deformation • Analyze fracture mechanics and ductile-brittle transition behaviour • Study fatigue behavior in engineering materials • Understand creep and superplasticity in materials			
Course Contents Unit I Elasticity - Analysis of stress, State of stress at a point, Normal and shear stress components, Stress components on an arbitrary plane, Principal stresses, Plane stress, Plane strain, Generalized Hooke's law, Atomic equivalent of Hooke's law, Elastic behavior of anisotropic and isotropic materials. Unit II Introduction to plastic deformation, Uniaxial stress-strain curves and flow instabilities, Effect of strain, strain-rate and temperature on flow stress, Stress-strain behavior of single crystals, Plastic flow in polycrystals, Deformation by slip and twins, critical resolved shear stress for slip, deformation of FCC, BCC and HCP. Flow and deformation behavior of polymer, ceramics and glasses. Unit III Ductile-brittle transition temperature (DBTT) through impact testing, factors effecting DBTT, Fracture of solids/Fracture mechanics, Crack deformation modes, Stress intensity factor, Crack growth based on energy balance - Griffith's criterion for brittle fracture, Strain energy release rate, Stress intensity factor, determination of fracture toughness (KIC). Unit IV Fatigue of engineering materials, S-N curve, Characteristics of fatigue fracture, Fatigue crack propagation laws, Strain-controlled fatigue, Fatigue failure models, Fatigue life calculations. Unit V Creep, mechanisms of creep, Creep of pure metals, solid solutions, MMCs, Creep of ceramics and polymers, creep asymmetry. Superplasticity in materials.			
Course Outcomes			
After completing this course, the students will be able to:			
CO-1: Understand the concepts of elastic behaviour of materials and Hooke's law			

CO-2: Knowledge of the plasticity of materials
CO-3: Comprehend the concepts of fracture mechanics
CO-4: Understanding the fatigue behavior of materials and its importance
CO-5 Learn the concepts of creep and its significance
Text Books
- Mechanical Behavior of Materials, Engineering Methods for Deformation, Fracture and Fatigue, 4th Edition. Norman E. Dowling - Mechanical Behavior of Materials, 2nd Edition. Marc Meyers and Krishan Chawla
Reference Books
<i>Deformation and fracture mechanics of engineering materials, 4th Ed., R. W. Hertzberg, John Wiley & Sons, 1995.</i> <i>Mechanical Metallurgy, 3rd Ed, George E Dieter, McGraw-Hill, New York, 1986.</i> <i>Mechanical Behavior of Materials, 2nd Edition, Thomas H. Courtney</i>

Course Code	Course Name	L – T – P	Credits
MM 606	Materials Processing	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand various processing techniques for polymers - Explore the manufacturing processes used in ceramics and glass - Study primary and secondary metal processing methods - Examine advanced metal forming and joining techniques			
Course Contents Unit I Processing of Polymers- Extrusion, compounding, fiber spinning, injection moulding, compression moulding, Unit II Processing of ceramics- Compaction, moulding, sintering, refractory manufacturing processes, glass manufacturing techniques. Unit III Processing of Metals-I: Casting, Hot working, Cold working, Rolling, Annealing, Forging, Extrusion, Defects in processing. Unit IV Processing of Metals-II: Wire drawing, Sheet metal forming, Hydroforming, Joining Techniques, Powder Metallurgy, Additive manufacturing.			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Understand the processing of polymers CO-2: Analyze the processing of ceramics CO-3: Comprehend the processing of metals CO-4: Learn advanced techniques of metal processing			
Text Books			
<i>Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.</i> <i>Manufacturing Processes and Materials for Engineers, L. E. Doyle, 1975. Powder</i>			
Reference Books			
<i>Metallurgy, Applications, Advantages and Limitations, Klar, Erhard, ASM, 1983, Ohio.</i> <i>Plastics Processing Data Handbook (2nd Edition), Rosato, Dominick, 1997.</i> <i>Plastic Injection Molding: Manufacturing by Douglas M. Bryce, 2007.</i> <i>Concise Encyclopedia of Plastics, Rosato, Marlene G, 2005</i>			

- *Extrusion: the Definitive Processing Guide and Handbook*, Giles, Harold F.; Wagner, John R.; Mount, Eldridge M, 2005.

Course Code	Course Name	L – T – P	Credits
MM 602L	Materials Processing and Testing Laboratory-II	0-0-6	3
Course Objectives: • Acquire practical skills in mechanical and electrochemical testing of metals and alloys • Gain hands-on experience with polymer processing techniques • Develop expertise in advanced characterization methods			
Course Contents 1 Electrochemical corrosion testing of metals and alloys 2 Wear and hardness testing of metals 3 Rolling and annealing of metals 4 Compounding of polymers 5 Extrusion of polymers and composites 6 Nanofiber manufacturing by electrospinning 7 Additive manufacturing of polymers 8 Calendaring of polymers 9 Analysis of texture using EBSD			
Course Outcomes After completing this course, the students will be able to: CO-1 Learn hands-on experiments on corrosion testing CO-2 Perform and learn mechanical testing of materials CO-3 Perform and learn metal processing techniques CO-4 Perform and learn polymer processing techniques			
Text Books			
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Reference Books			
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Course Code	Course Name	L – T – P	Credits
PGC-602	Communication Skills and Personality Development	2-0-0	2
Course Objectives:			
Course Contents Unit I: English for Research Paper Writing Unit II: Disaster Management Unit III: Sanskrit for Technical Knowledge Unit IV: Value Education Unit V: Constitution of India Unit VI: Pedagogy Studies Unit VII: Stress Management by Yoga Unit VIII: Personality Development through Life Enlightenment Skills			

Course Outcomes
Text Books
Reference Books

Course Code	Course Name	L – T – P	Credits
MM 607	Polymer and Composite Technology	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand the fundamentals of polymers Develop knowledge of physical and analytical techniques - Gain insight into conventional and advanced polymer composites - Explore various composite manufacturing techniques - Examine the use of polymers and composites in defense and aerospace			
Course Contents Unit I Polymers: Classification of Polymers, Co-Polymers, Thermoset and Thermoplastics, Crystalline and Amorphous Polymers, Polymerization, Degree of Polymerization, Glass transition temperature, Molecular weight of polymer and its determination by various techniques. Unit II Physical methods of polymer analysis such as IR, DSC, TGA, XRD, etc., Viscoelasticity, Polymer blends and alloys: thermodynamics, morphology, and properties Unit III Composites: Conventional polymer composites, Fiber reinforced composites (carbon, glass, aramid, etc.), Nanofillers and their composites; Recycling of macro and micro polymer composites Unit IV Composite manufacturing techniques: Solution-cast, Melt-mixing, Extrusion, Compression molding, Resin transfer, Resin infusion, Vacuum casting and electrospinning. Unit V Defence Applications: Coatings (Superhydrophobic, Self-Healing), Fire retardant, Corrosion Resistant, EMI Shielding, Environmental responsive polymers (Self-healing, Phase change and Shape Memory), Polymer composites in aerospace applications. Service life prediction methodologies of polymers and composites			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Understanding classifications and characteristics of polymers CO-2: Analysis of the polymer properties CO-3: Conception of composite and nanofiller CO-4: Cognizance of Manufacturing of composites CO-5: Case studies of polymers and composites for Defence Applications			
Text Books			
- V.R. Gowariker, <i>Polymer Science</i>, Wiley Eastern, 1995 F. N. Billmeyer, <i>Textbook of Polymer Science</i>, Wiley Interscience, 1971.			
Reference Books			
- Kumar and S. K. Gupta, <i>Fundamentals and Polymer Science and Engineering</i>, Tata McGraw-Hill, 1978 - Epel, J.N.: <i>Engineering Plastics, Engineering Materials Handbook</i>, ASM International 1988.			

- *Brydson, A.J.: Plastics Materials, Princeton, N.J., 1966*

Course Code	Course Name	L – T – P	Credits
MM 608	Mathematics for Computational Materials Engineering	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Develop a strong foundation in linear algebra • Understand core concepts of calculus • Apply vector calculus tools • Learn the fundamentals of numerical methods • Gain exposure to modern computational tools			
Course Contents Unit I Algebra of real matrices: Determinant, inverse and rank of a matrix; System of linear equations (conditions for unique solution, no solution and infinite number of solutions); Eigenvalues and eigenvectors of matrices; Properties of eigenvalues and eigenvectors of symmetric matrices, diagonalization of matrices; Cayley-Hamilton Theorem. Unit II Limit, Continuity and differentiability; Maxima and minima; Partial derivatives; Total derivative. Unit III Gradient, divergence and curl; Line integrals, and Green's theorem. Unit IV Concepts of discretization in space/time, implicit, explicit; Taylor's series; Solution to ODEs; Classification of second-order linear partial differential equations; Method of separation of variables: One-dimensional heat equation and two-dimensional Laplace equation. Unit V Basics of CFD, AI & ML, FEM, ThermoCalc and Dictra Softwares.			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Understand the basics of Linear Algebra CO-2: Recognize the principles of advanced calculus CO-3: Basic knowledge of vector calculus CO-4: Utilise numerical methods to solve differential equations CO-5 Understanding of some commercial software			
Text Books			
• <i>Advanced engineering mathematics: Kreyszig; Wiley.</i> • <i>Advanced engineering mathematics: Jain/Iyenger; Narosa</i>			
Reference Books			
• <i>Advanced engineering mathematics: Peter V. O'Neil Cengage Learning</i> • <i>Advanced engineering mathematics: Alan Jeffery; Academic Press</i>			

Course Code	Course Name	L – T – P	Credits
MM 609	Fatigue, Fracture and Failure Analysis	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand the fundamental principles of fatigue behaviour - Analyze the influence of structural and material factors Gain knowledge of fracture mechanics - Explore advanced concepts in brittle fracture - Apply fracture toughness parameters			
Course Contents Unit I Stress Cycles, S-N Curve, Interpretation of Fatigue Data, Endurance Limit, Effect of Mean Stress on Fatigue, Cyclic Stress-Strain Curve, Low-Cycle Fatigue, Plastic Strain & Fatigue Life, Safe-Life and Fail-Safe Design Philosophies, Rotary bending fatigue, and torsional fatigue. Unit II Effect of Structural Features, Fatigue Crack Propagation, Stress Concentration & Fatigue, Size & Surface Effect, Effect of Metallurgical Variables & Enhancement of Fatigue Life, Unit III Classification of Fracture, Theoretical Strength of Metals, Griffith Theory of Brittle Fracture, Metallographic features of Fracture, Fractography Unit IV Dislocation Theory of Brittle Fracture, Effect of Tri-axial Stress, Strain Energy Release Rate, Stress Intensity Factor, Unit V Fracture Toughness & Design, KIC, CTOD, J-Integral, R-Curve, Toughness of Metals & Alloys. Stress corrosion cracking. Case studies on failure analysis			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Detailed introduction to fatigue failure of materials CO-2: Analyze the effect of fatigue crack propagation and improving fatigue life CO-3: Conception of fracture mechanics CO-4: Conceptualize stresses induced during brittle fracture CO-5: Understanding fracture toughness in metals and alloys			
Text Books			
<i>Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.</i>			
Reference Books			
<i>Deformation and fracture mechanics of engineering materials, 4th Ed., R. W. Hertzberg, John Wiley & Sons, 1995.</i> <i>Elementary engineering fracture mechanics By David Broek Noordhoff 1974.</i> <i>Fatigue and Fracture of Metals, W. M. Murray, John Wiley, 1952.</i>			

Course Code	Course Name	L – T – P	Credits
MM 610	Introduction to Computational Materials Engineering	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Develop proficiency in programming languages - Understand the principles of modeling and simulation - Apply numerical and stochastic methods - Gain experience with data-driven modelling - Develop skills in scientific data visualization and dimensionality reduction			

Course Contents	
Unit I Review the fundamentals and applications of programming in high level languages such as Python / MATLAB and low-level languages such as C / C++	
Unit II Introduction to modeling and simulations: Analytical solution of first-order nonlinear differential equation followed by their numerical solution; Numerical solution of Fickian laws in 1D (using low-level language) and 3D (using advanced solvers); Random Walker model	
Unit III Sampling methods to obtain numerical solution and its application to solve ferromagnetism in statistical mechanics; Diffuse-interface mesoscale models: Cahn-Hilliard model	
Unit IV Data driven modeling: Supervised and Unsupervised models, Fitting and visualization of multidimensional data; Data analytics using principal component analysis.	
Course Outcomes	
After completing this course, the students will be able to:	
CO-1: Understand the basics of programming	
CO-2: Implement the analytical and numerical solution to partial differential equations utilised in Materials Engineering	
CO-3: Analyze the mesoscopic modelling techniques	
CO-4: Understand the principles of data-driven modelling	
Text Books	
• <i>Introduction to Computational Materials Science – Richard LeSar, Cambridge University Press (2013). ISBN: 9781316614877</i>	
Reference Books	
• <i>Mathematical Methods for Physics and Engineering, 3rd Edition – R.F. Riley, M.P. Hobson, S.J. Bence, Cambridge University Press (2012). ISBN: 9780521139878</i> • <i>Integrated Computational Materials Engineering (ICME) for Metals – Mark F. Horstemeyer, TMS (2012). ISBN: 9781118022528</i> • <i>Integrative Computational Materials Engineering : Concepts and Applications of a Modular Simulation Platform – Georg J. Schmitz and Ulrich Prahl, Wiley-VCH Verlag GmbH & Co (2012). ISBN: 9783527330812</i>	

Course Code	Course Name	L – T – P	Credits
MM 611	Nanomaterials and Their Applications	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamentals of nanostructures and nanomaterials • Understand the structure and properties of specific nanomaterials • Explore interfacial phenomena and biological interactions • Examine the thermodynamic, mechanical, and functional properties • Analyze the diverse applications of nanotechnology			
Course Contents			
Unit I Overview of Nanostructures and Nanomaterials; Synthesis of Nanomaterials: Types and strategies for synthesis of nanomaterials;			
Unit II Crystalline nanomaterials and defects therein; Hybrid nanomaterials; Multiscale hierarchical structures built out of nanosized building blocks (nano to macro); Nanomaterials in Nature: Nacre, Gecko, Teeth; Nanostructures: Carbon Nanotubes, Fullerenes, Nanowires, Quantum Dots. Graphene, its characteristics and applications			

Unit III Cells response to Nanostructures; Surfaces and interfaces in nanostructures, Ceramic interfaces, Superhydrophobic surfaces, Grain boundaries in Nanocrystalline materials, Defects associated with interfaces;

Unit IV Thermodynamics of Nanomaterials; Overview of properties of nanostructures and nanomaterials; Overview of characterization of nanostructures and nanomaterials; Deformation behaviour of nanomaterials: Fracture and creep; Nanomechanics and nanotribology; Electrical, Magnetic and Optical properties;

Unit V Applications of Nanotechnology in various fields: Defence, Aerospace and Marine Nanotechnology, Renewable energy, solar energy, fuel cells, Reinforcement in Ceramics, Drug delivery, Electronics etc.

Course Outcomes

After completing this course, the students will be able to:

CO-1: Learn the strategies for synthesis of nanomaterials

CO-2: Classification of nanomaterials and analysis of the defects in crystalline nanomaterials

CO-3: Analyze the structure property variation when reduced to nanoscale.

CO-4: Understanding thermodynamics of nanomaterials

CO-5: Case studies of nanomaterials in Defence applications

Text Books

- *T. Pradeep, NANO: The Essentials, Tata McGraw-Hill Publisher, 2007. ISBN-13:978- 0-07-061788-9.*

Reference Books

- *K. Haghi, G. E. Zaikov, Advanced Nanotube and Nanofiber Materials, Nova Science Publishers Inc, 2012*
- *Vladimir V. Mitin, Viatcheslav A. Kochelap, Michael A. Stroscio, Introduction to Nanoelectronics: Science, Nanotechnology, Engineering, and Applications, Cambridge University Press, 2008*

Course Code	Course Name	L – T – P	Credits
MM 612	Non-Destructive Evaluations	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the principles and techniques of conventional non-destructive testing (NDT) • Develop an understanding of advanced NDT techniques • Explore modern imaging and detection methods • Familiarize students with specialized NDT approaches • Apply NDT techniques to real-world case studies			
Course Contents Unit I Visual Inspection, Liquid Penetrant Testing, Magnetic Particle Testing, Unit II Eddy Current Testing, Ultrasonic Testing, Laser-based testing, Hot inspection. Unit III Acoustic Emission Technique, Radiography Technique Unit IV Residual Stress Analysis, In-situ Metallography, Automation and Robotics in NDT, Basics of modelling techniques Unit V Case study: Grain Size, Weldment, and other Structural Components.			
Course Outcomes			
After completing this course, the students will be able to:			

- CO-1: Detailed introduction to handy NDT (Non-destructive techniques)
 CO-2: Cognizance of Eddy current and ultrasonic testing
 CO-3: Conception of acoustic emission and radiography techniques
 CO-4: Understanding automated NDT techniques
 CO-5: Case studies on NDT techniques application

Text Books

- *Non-destructive Testing of welds*, Baldev Raj, C.V. Subramanian and T. Jayakumar, Narosa Publishing House, 2000, Delhi.

Reference Books

- *International Advances in non-destructive testing*, (Ed.) W. J. McGonnagle, Gordon and Breach Science Publishers, 1981, NY.
- *Non-destructive Testing, Views, Reviews, Previews*, (Ed.) L.L. Alston, Oxford University Press, 1970
- *Nondestructive Evaluation and quality control*, ASM handbook, Volume 17, ASM International

Course Code	Course Name	L – T – P	Credits
MM 613	Polymer Blends and Nanocomposites	3-0-0	3

Course Objectives: The primary objectives of this course are to:

- Introduce the fundamentals of polymer blends, composites, and nanocomposites
- Understand the structure-property relationships
- Explore the types, synthesis, and functionalization of nanostructured materials
- Learn and compare processing techniques
- Assess the recyclability, environmental implications, and advanced applications

Course Contents

Unit I Introduction to polymer blends and composites, nanostructured materials and nanocomposites. Thermodynamic aspects of polymer miscibility, mixing, factors governing miscibility, immiscible polymers, and phase separation. Importance of interface on the property development, compatibilizers and compatibilization.

Unit II Blends of amorphous & semi-crystalline polymers, inter-penetrating networks, thermoplastic and thermoset blends, rubber toughened polymers, particulate and fiber reinforced composites.

Unit III Nanostructured materials like nanoclay, carbon nanotubes, graphene, magnetic nanoparticles etc., and polymer nanocomposites. Surface treatment of the reinforcing materials and interface/interphase structures of composites/nanocomposites.

Unit IV Various processing techniques like solution mixing, melt processing. Physical and thermo-mechanical properties of polymer blends, composites and nanocomposites.

Unit V Recyclability, environmental impact, and potential Applications in Defence.

Course Outcomes

After completing this course, the students will be able to:

- CO-1: Learn the basics and thermodynamics of polymer blends
 CO-2: Knowledge of classifications of blends and composites
 CO-3: Understand concepts of nanomaterials and their interface with
 CO-4: Learn processing methods for polymer blends and nanocomposites

CO-5: Case studies of polymer nanocomposites in defence applications
Text Books
• <i>Textbook of Polymer Science, Fred W. Billmeyer (Wiley)</i> • <i>Polymer alloys and blends by L A Utracki</i>
Reference Books
• <i>Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)</i>

Course Code	Course Name	L – T – P	Credits
MM 614	Biomaterials	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamental concepts of biomaterials and tissue engineering • Explore different classes of biomaterials • Understand the properties and applications of nano-biomaterials • Develop knowledge of fabrication and imaging techniques • Analyze real-world bioinspired case studies and applications			
Course Contents Unit I Introduction to biomaterials, Tissue Engineering, Biocompatibility, Biodegradation Biofluids and medical devices, Biostructures Unit II Ceramic-based biomaterials, metallic biomaterials, polymer-based biomaterials, Biofluidic, medical devices, Biostructures Unit III Nano-biomaterials: Self-assembly of nanomaterials, hydrophilic, hydrophobic and surfaces, biomimicking Unit IV Medical imaging, electrospinning of scaffold structures, Additive manufacturing of medical devices, biofluidics and biostructure Unit V Case studies: Lotus leaf, Gecko feet, Nacre/Bone. Application of nanocomposite biomaterials: artificial biomaterials, antidrag coatings, self-cleaning surfaces, sensors, Riboswitches			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Detailed discussion of biomaterials along with applications CO-2: Elaborate the classification of biomaterials CO-3: Cognizance of nanobiomaterials CO-4: Project several utilizations of biomaterials CO-5: Case studies of biomaterials for medical applications			
Text Books			
• <i>Biomaterials- An Introduction, Joon Park- Publisher Springer</i>			
Reference Books			
• <i>Biomaterials- Principals and Applications- Joon Park- CRC Press</i> • <i>Handbook of Biomaterial Properties- Garth Hastings- Springer</i> • <i>Handbook of Biomaterials Properties- William Murphy- Springer</i> • <i>Handbook of Biomaterial Properties- Jonathan Black- Chapman and Hall</i>			

Course Code	Course Name	L – T – P	Credits
MM 615	Design of Materials	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand the fundamentals of diffusion in materials - Gain knowledge of metallic materials and their structures - Explore the kinetics and mechanisms of phase transformations - Analyze the mechanical behavior of ceramics - Examine composite materials and their mechanical enhancements			
Course Contents Unit I Diffusion: First and Second law of diffusion, Solution to diffusion equations and error function, Types of diffusion, Kirkendall effect and applications Unit II Metals and Metal Structures: Generic classes of Metallic alloys and applications, Equilibrium shapes of grains and phases; Case studies in phase diagrams: Soft solders, Zone Refinement of Semiconductors, Bubble-free Ice Unit III Diffusive and Displacive Transformations: Kinetics of nucleation, diffusive and Martensitic phase transformations; Case Studies in Phase Transformations: Fine grain castings, Rapid solidification and amorphous materials; Light alloys: Age-hardening and thermal stability, Unit IV Mechanical properties of Ceramics, Statistics of Brittle fracture: Flaw size and dispersion of strength, Weibull distribution, Design of pressure windows Unit V Composites: Fibrous, particulate, and foamed composites, Improving stiffness, strength and toughness. Case studies in Defence applications: Turbine blades, bullet-proof vests, uses of metal matrix composites and carbon-carbon composites. Heat-resistant composites, and Bullet-proof composites			
Course Outcomes After completing this course, the students will be able to: CO-1: Principles of solid-state diffusion, their equation along with solution. CO-2: Applications of several mechanical alloys and their phase diagrams CO-3: Cognizance of phase transformation processes CO-4: Understanding ceramics and the statistics of brittle fracture CO-5: Demonstration of Solid state, Sol-Gel, Hydrothermal and Co-precipitation process			
Text Books <i>Engineering Materials 1</i> Michael F. Ashby and David R. H. Jones; Butterworth-Heinemann, Elsevier Publications <i>Engineering Materials 2</i> Michael F. Ashby and David R. H. Jones; Butterworth-Heinemann, Elsevier Publications			
Reference Books <i>D. A. Porter and K. E. Easterling, Phase transformations in Metals and Alloys, Chapman and Hall, London, 1996</i> <i>Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992</i>			

Course Code	Course Name	L – T – P	Credits
MM 616	Magnetism and Magnetic Materials	3-0-0	3

Course Objectives: The primary objectives of this course are to: • Understand the fundamental origins of magnetism • Explore classical and quantum magnetic behaviors • Analyze magnetic ordering phenomena • Study magnetic anisotropy and domain behaviour • Examine the properties and applications of magnetic materials	
Course Contents Unit I Moment of a current loop, Orbital angular momentum and magnetic moments, Spin magnetic moment, gyromagnetic ratio, Vector atom model Unit II Classical diamagnetism, Superconductors, Paramagnetic moments, classical paramagnetic. Unit III Weiss molecular field, Brillouin function and spontaneous magnetization, Curie Weiss law, Magnetocaloric effect, Exchange interaction, Spin waves, Antiferromagnetism and Néel temperature, Exchange Bias effect and applications, Ferrimagnetism: Spinel structure and Ferrite moments Unit IV Uniaxial and Cubic anisotropy, Shape anisotropy, Crystal field effects, Origin of magnetic domains, Equilibrium domain size and domain wall, Néel and Bloch Walls Unit V Differentiation between Soft and hard magnetic materials, Finemet alloys, Rare earth permanent magnets, Magnetostriction: TERFNOI-D, Multiferroics, Magnetic Anomaly Detection.	
Course Outcomes	
After completing this course, the students will be able to: CO-1: Brief introduction to moment of magnetic materials CO-2: Analysis of traditional types of magnetism CO-3: Conception of effects of magnetism and application CO-4: Cognizance of material characteristics affecting on magnetism CO-5: Understand different types of magnetic materials	
Text Books	
• <i>Introduction to Magnetic Materials, B. D. Cullity and C. D. Graham; IEEE Press, A. Jon Wiley & Sons Publications</i>	
Reference Books	
• <i>Fausto Florillo, Measurement and Characterization of Magnetic Materials, Elsevier Academic Press, 2004</i> • <i>Modern magnetic Materials: Principles and applications Robert C. O'Handley; Wiley-Interscience Publications</i> • <i>Physics of magnetism and Magnetic materials</i> • <i>K. H. J. Bushaw and F. R. de Boer; Kluwer Academic Publishers</i>	

Course Code	Course Name	L – T – P	Credits
MM 617	Heat-treatment of Metals and Alloys	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand fundamental heat treatment processes for steels • Learn surface hardening techniques • Explore advanced hardening methods • Gain knowledge of heat treatment practices for various alloys			

Study the relationship between deformation and annealing
Course Contents Unit I Steel Heat-Treatment, Annealing, Stress relief annealing, Process Annealing, Normalizing, Spheroidizing, Tempering, Quenching, Hardening, TTT Curve, Hardenability Unit II Case hardening, carburizing, Nitriding, Boronizing Unit III Flame hardening, Induction hardening, Laser hardening, Electron beam hardening Unit IV Heat treatment of Stainless Steel and Cast Iron, Aluminum, Titanium, Magnesium, and Ni-based alloys Unit V Deformation and annealing.
Course Outcomes After completing this course, the students will be able to: CO-1: Explore several heat treatment processes and TTT curve. CO-2: Analyse the case hardening heat treatment processes CO-3: Comprehend the advanced heat treatment methods CO-4: Identify different heat treatment process for specific metals CO-5: Demonstration of after effects of heat treatment
Text Books <i>Heat Treatment Principles & Techniques, TV Rajan, CP Sharma & Ashok Sharma Prentice Hall of India, New Delhi, 2007.</i> <i>Metallurgy for Engineers-EC Rollason, 4th Ed, Edward Arnold, UK, 1973.</i> <i>Introduction to Physical Metallurgy, S H Avner, TATA Mc-Graw Hill, New Delhi, 2001.</i>
Reference Books <i>Engineering Physical Metallurgy by Yuri Lakhtin, Moscow, MIR Publishers, 1963.</i> <i>Grain boundary migration in metals: thermodynamics, kinetics, applications, G. Gottstein & L. Shvindlerman, Boca Raton (FL), CRC, 1999.</i>

Course Code	Course Name	L – T – P	Credits
MM 618	Materials for High-Temperature Applications	3-0-0	3
Course Objectives: The primary objectives of this course are to: - Understand the melt processing techniques of superalloys - Learn about Oxide Dispersion Strengthened (ODS) alloys and powder metallurgy methods - Analyze deformation and wear behaviors - Explore the design and processing of fiber-reinforced superalloy composites and metal matrix composites - Gain knowledge of the processing methods and properties of advanced structural ceramics			
Course Contents Unit I Melt processing of Superalloy, Single crystal Superalloy, Processing of Superalloy, Alloying effect. Unit II Oxide Dispersion Strengthened alloys. Powder Metallurgy Unit III High temperature deformation, Room and high temperature Wear, Advanced coating materials, High Entropy Alloys			

Unit IV Fiber Reinforced Composite Superalloy, Metal matrix composites Unit V Processing and properties of advanced Structural Ceramics
Course Outcomes
After completing this course, the students will be able to: CO-1: An introduction to high temperature materials: Alloys and non-metals and their property requirements CO-2: Concept of creep and high temperature oxidation behaviour and their mitigation. CO-3: Understand the application, process and properties of high-speed steels CO-4: Understand the structure and processing of Ni-based superalloys for aero-engine applications CO-5: Identify advanced structural ceramics for high-temperature applications
Text Books
• <i>Superalloys, supercomposites and super ceramics</i>, ed. J. K Tien and T. Caulfield, Academic Press, 1989, Boston. • <i>High temperature structural materials</i>, R. W. Cahn, Chapman and Hall, 1996, London.
Reference Books
• <i>Materials for High Temp. Engg. Applications</i>, G. W. Meetham and M.H. Van de Voorde, Springer, 2000, Berlin. • <i>Friction, wear and Lubrications</i>, K.C. Ludema, CRC Press, 1996. • <i>Powder Metallurgy: Science, Technology, and Materials</i> Anish Upadhyaya and G. S. Upadhyaya, Taylor & Francis, 2011

Course Code	Course Name	L – T – P	Credits
MM 619	Advanced Steel Technology	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Understand key strengthening mechanisms in steels • Analyze the microstructural transformations and properties of low carbon steels • Examine medium and high carbon steels • Gain detailed knowledge of fully pearlitic microstructures • Explore special steels such as bainitic, maraging, stainless, and TWIP steels			
Course Contents Unit I Strengthening mechanisms: Work hardening, Solid solution strengthening, Grain size refinement, Dispersion strengthening, Physical Metallurgy of Steel, Precipitation Techniques Unit II Low Carbon steels: Austenite to ferrite transformation, High strength low alloys steels, Interstitial free steels, Dual phase and TRIP steels Unit III Medium and high carbon steels: Austenite to pearlite transformation, Ferritic- pearlitic microstructures in medium carbon steels, Austenite to Cementite transformation, Fully pearlitic microstructures: Rail steels, high strength steel wires Unit IV Fully pearlitic microstructures: Rail steels, high strength steel wires Unit V Special steels: Bainite: Upper and lower Bainite microstructures, Bainite transformation mechanisms and transition, nanostructured Bainite; Maraging steels, Stainless steel, TWIP steels, Case studies for defence applications.			
Course Outcomes			
After completing this course, the students will be able to:			

- CO-1: Comprehend different strengthening mechanisms in steel
- CO-2: Introduce low carbon steel and their characteristics
- CO-3: Explore medium and high carbon steel along with their transformations
- CO-4: Importance of pearlite microstructures
- CO-5: Applications of special steel materials like bainite and case studies for defence applications.

Text Books

- *Steels: Processing, Structure, and Performance, George Krauss; ASM International*

Reference Books

- *Steels: Microstructure and Properties HKDH Bhadeshia and Sir R. Honeycomb; Butterworth-Heinmann, Elsevier Publications*

Course Code	Course Name	L – T – P	Credits
MM 620	Military Materials	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamental requirements of metallic materials for military applications • Understand the properties and applications of special alloys and advanced materials for armor systems • Explore material solutions for ammunition systems • Analyze the material requirements for aerospace defense applications • Study specialized alloys and emerging materials for naval and multifunctional defense applications			
Course Contents Unit I Overview metallic materials for military application, needs of complex metals and alloys required for modern and sophisticated warfare weapons systems. Conventional alloys for military application: Functional requirements of cartridge case and manufacture, Brass and steel cartridge cases, Cased ammunition. Steel shell bodies – High explosive squash head, Steel guns barrels- Direct fire tank guns, Indirect fire artillery guns, Alloys for military bridges: Mild steel- Bailey bridge and heavy girder bridge, Aluminum alloy – Medium girder bridge and BR 90. Unit II Special Alloys for Armour applications: Rolled Homogeneous Armour steels: Kanchan armour for Arjun tank, Steel armour plate, Aluminum alloy armour for light armoured vehicles, Body armour. Sensor Materials, Advanced Composites, High temperature ceramics, composite armour plates Unit III Alloys for ammunition applications: Ferrous fragmenting projectiles: Cast iron mortar bomb bodies, Steel 155 mm anti-personnel artillery shell body. Conical shaped charge weapon system, Hydrodynamic penetration, Copper charge penetrators. Kinetic energy penetrators: Armor piercing fin stabilized discarding Sabot, Tungsten heavy alloys as long rod penetrator, Recent development, Single crystal penetrators Unit IV Alloys for aerospace applications: Materials required for engine parts, Superalloys for high temperature applications, Single crystal blades made of Ni-based super alloys, Aerospace grade low-density high-strength Ti and Al alloys, Ultra-high-strength steel with toughness for missile applications. Coating materials for Gun Barrels. Unit V Special alloys for naval applications: Special alloys with functional properties: Advanced magnetic materials - Ultra high energy product permanent magnets, emerging materials such as nanomaterials and smart materials, Ultrahigh temperature material.			

Course Outcomes
After completing this course, the students will be able to:
CO-1: An overview of special materials requirements for military applications.
CO-2: Requirement of materials, their properties and processes for armor protection systems.
CO-3: Discussion of specific required for ammunition applications and their properties and processes.
CO-4: Special alloys and their stringent properties required for building fighter aircraft.
CO-5: Special steels and their process for naval vessels.
Text Books
• <i>Alistair Doig, Military metallurgy, Maney publishing, 2002</i>
Reference Books
• <i>Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992</i>
• <i>Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.</i>
• <i>Paul J Hazell, Armour Materials Theory and Design, CRC Press, 20</i>

Course Code	Course Name	L – T – P	Credits
MM 621	Introduction to Corrosion	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamental concepts of corrosion • Understand electrode kinetics and polarization phenomena • Apply mixed potential theory to practical corrosion scenarios • Identify and analyze various forms of corrosion • Explore key electrochemical equations and factors influencing corrosion			
Course Contents Unit I What is corrosion – definition & fundamentals, Importance & Economic Impact of Corrosion, Thermodynamics of Corrosion, Electrochemical principles of Corrosion, Potential versus pH (Pourbaix) diagrams – Calculation & Construction of E – pH diagrams & its practical use. Copper, Aluminium & general corrosion diagram, Mixed Potential or Evans diagram & its application. Unit II Electrode Kinetics and Polarization Phenomenon: Electrode – Solution interface – Definition & types of polarization. Exchange current density and polarization relationships. Polarization techniques – corrosion rate determination Unit III Mixed Potential concepts and Basics. Mixed potential theory – bimetallic couples. Activation and diffusion controlled mixed electrodes. Origin of electrochemical noise and its application. Unit IV Forms of Corrosion – Uniform, Localized & Metallurgical influenced – Pitting, Crevice, Galvanic & Intergranular Corrosion, Mechanically Assisted, Environmentally Induced & Microbiologically influenced Corrosion. Unit V Nernst equation, EMF Series and Galvani Series, Stern-Gary eqn. Mechanical and environmental factors affecting corrosion, materials selection for different Defence applications. Passivity, trans passivity and breakdown, corrosion resistant and high temperature resistant materials.			
Course Outcomes			
After completing this course, the students will be able to:			

- CO-1: Introduction to thermodynamics of corrosion
 CO-2: Identification of electrode kinetics and polarisation
 CO-3: Cognizance of mixed potential theory
 CO-4: Recognized different forms of corrosion
 CO-5: Case studies of environmental factors causing corrosion

Text Books

- *Mars G. Fontana, Corrosion Engineering, 3rd Ed., McGraw-Hill, Singapore, 1987*

Reference Books

- *H.H. Uhlig and R.W. Revie, Corrosion and its control, 3rd Ed., John Wiley, Singapore, 1991*

Course Code	Course Name	L – T – P	Credits
MM 622	Welding Science and Technology	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the classification and fundamentals of welding processes • Understand the thermal and metallurgical effects of welding • Analyze welding metallurgy under rapid cooling conditions • Apply welding principles to specific metals and alloys • Explore pre- and post-weld heat treatments and modern welding techniques			
Course Contents Unit I Classification of welding processes, study of welding arc characteristics, metal transfer during arc welding, heat flow in welding, Chemical reactions in welding, weld pool solidification, effect of welding process parameters on the macro- and micro-structure of weld metal. Solid state welding processes Unit II Thermal cycles in the heat-affected zone. Phase transformations in the weld metal and the heat affected zone. High power density processes, such as laser and electron beam welding. Weldability of Similar and Dissimilar Metals, Advanced Welding Processes and Dissimilar Metal Welding Unit III Welding metallurgy under high cooling rates. Phenomena of hot-cracking and cold cracking. Residual stresses and distortion during and after welding, Fatigue and fracture of weldments. Sensitized phenomena, Soundness of Welding. Unit IV Application of the above principles to welding of carbon and alloy steels, cast irons, stainless steels, aluminum and titanium alloys. Weld decay, problems associated with the welding of metals and alloys. Stabilized alloy Unit V Pre and post-welding Heat treatment processes, Failure analysis, Modern welding processes (laser welding, electron beam welding and friction welding)			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Analyse the welding processes CO-2: Understand the physics of welding CO-3: Correlation of metallurgy and welding CO-4: Understand the welding of various alloys CO-5: Analyse the failures in welding and their remedies			

Text Books
• <i>K. Easterling, Introduction to Physical Metallurgy of Welding, Butterworths Pub., 1983.</i>
Reference Books
• <i>Sindo Kou, Welding Metallurgy, John Wiley & Sons, New York, 1987.</i> • <i>S.A. David (Ed.), Advances in Welding Science and Technology, American Society for Metals, Ohio, 1986.</i>

Course Code	Course Name	L – T – P	Credits
MM 623	Corrosion in Hostile Environments	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamental principles of corrosion • Understand high-temperature corrosion phenomena • Learn advanced corrosion measurement and analysis techniques • Analyze real-world case studies of corrosion • Evaluate high-temperature corrosion in industrial systems			
Course Contents Unit I Introduction to corrosion, Different forms of corrosion, Electrochemical principles of Corrosion, Localized & Metallurgical influenced Pitting, Crevice, Galvanic & Intergranular Corrosion. Aspects of thermodynamics, corrosion mitigation Unit II Introduction, high temperature gaseous reaction (dry), single metal-single oxidant systems, aspects of thermodynamics, kinetics, transport properties, scale morphologies, electrochemical emphasis, various forms of high temperature corrosion including molten salt corrosion, thermodynamic phase stability in metal/gas systems- predominance area diagrams; Unit III Electrochemical impedance, Tafel, Open circuit potential, determination of corrosion rate, defect interactions, scale growth kinetics and mechanisms, Wagner's parabolic scale growth process, other types of kinetics laws and mechanisms, morphological aspects in the growth of thick scales. Unit IV Case studies – Corrosion in seawater, corrosion in military environments, biofouling. Unit V Case studies – High temperature corrosion in steam and gas turbines, high temperature in Gasifiers and Boilers			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Introduction to various forms of corrosion, concept of free energy, partial pressure and related thermodynamics, corrosion mitigation CO-2: To learn various form of high temperature corrosion CO-3: Analysis of corrosion data and identify corrosion rate CO-4: Understand corrosion in various room temperature applications CO-5: Understand different applications of high temperature corrosion			
Text Books			
• <i>Per Kofstad, High Temperature Corrosion, Elsevier Applied Science, 1988.</i> • <i>Mars G. Fontana, Corrosion Engineering, 3rd Ed., McGraw-Hill, Singapore, 1987</i>			
Reference Books			
• <i>N. Birks and G.H. Meier, Introduction to Oxidation of Metals, Edward Arnold, London, 1983.</i> • <i>A.S. Khanna, Introduction to High Temperature Oxidation and Corrosion, ASM International, Materials Park, Ohio, 2002.</i>			

- *Phase transformation in metals and alloys, Porter and Easterling.*

Course Code	Course Name	L – T – P	Credits
MM 624	Corrosion Mitigation	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamentals of protective coatings and corrosion inhibitors • Understand the requirements and classification of protective coatings • Explore the principles and mechanisms of cathodic and anodic protection • Analyze corrosion protection strategies for extreme environments • Apply corrosion protection knowledge to real-world defense-related case studies			
Course Contents Unit I Protective Coatings – Introduction, coatings & Coating Processes, Supplementary protection systems, Surface preparation. Classification of inhibitors, Corrosion inhibition Mechanism, Selection of an inhibitor system Unit II Requirement of protective coatings, classification of organic and inorganic coatings, metallic coatings, electrodeposition and electroless coatings. Paint coatings for corrosion protection, role of resins, pigment, additives and solvents, Advanced coatings (CVD, ALD and PVD). Unit III Cathodic and Anodic Protection – principles & classifications, mechanism of Cathodic and anodic protections – influencing factors and Monitoring Unit IV Corrosion protection in extreme environment such as nuclear irradiation, high pressure etc. Unit V Case studies relevant to Defence Applications: (Superhydrophobic coatings, anti-barnacles coating, corrosion control of underground pipelines, storage tanks, overhead pipelines, offshore structures, ship hulls, risers, reinforced bars and concrete structures, PVD and CVD based coatings)			
Course Outcomes After completing this course, the students will be able to: CO-1: Understand importance of protective coating process and their classification CO-2: Knowledge of the fundamentals and applications of coating techniques CO-3: Cognizance of factors affecting cathodic and anodic protection CO-4: Demonstrated corrosion protection in extreme environmental conditions CO-5: Case studies for Defence Applications			
Text Books • <i>Corrosion: Environment and Industries, Metals Handbook, Vol. 13c, Park Ohio, 1984, 10th Ed., ASM Metals, Ohio, 1987.</i> • <i>N.D. Tomashov, Theory of Corrosion and Protection of Metals, Macmillan, 1967.</i> • <i>M.G. Fontana, Corrosion Engineering, 3rd Ed., McGraw-Hill, 1985.</i> 4. <i>H.H. Uhlig, Corrosion & Corrosion Control, Wiley, 1985.</i>			
Reference Books • <i>R. Lambourne and T.A. Strivens, Paint and Surface Coatings, Ellis Horwood D, Chichester, 1987.</i> • <i>C.G. Munger, Corrosion Prevention by Protective Coatings, NACE Pub., Houston, 1984.</i>			

- *Surface Finishing, Cleaning & Coatings, ASM Handbook, Vol. 5, 1994.*
- *J. Biesiek and J. Weber Portcullis, Electrolytic and Chemical Conversion Coatings, Red Hill Press, 1976.*
- *F.A. Lowenheim, Electroplating: Fundamentals of Surface Finishing, McGraw-Hill, New York, 1978.*

Course Code	Course Name	L – T – P	Credits
MM 625	Composite Materials	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamental concepts of composite materials • Differentiate between macroscale and microscale material behaviour • Develop an understanding of the mechanics and thermodynamics of composite deformation • Explore fiber materials used in composites • Understand the design, processing, and applications of fiber-reinforced composites			
Course Contents Unit I General principles and basic concepts, terminologies, classifications, composites based on micrometer fibers, natural composites such as nacre, shells, bone, dentin, etc. Matrix phase, reinforcement, dispersion vs. distribution, interfacial properties. Unit II Macroscale vs. microscale, Lennard-Jones potential curves, elastic modulus prediction using theoretical cohesive strength, Griffith's theory, and experiments on the strength of materials. Unit III Stress and strain, thermodynamics of deformation, the origin of Hooke's law, basic mechanics of composites, rule of mixture, micromechanical models (Halpin-Tsai, Kelly-Tyson, Cox, etc.) Unit IV Fibers, short, continuous fibers, different fiber (glass, carbon, aramid, UHMWPE, SiC, boron etc.) production and their properties, flexibility, compressibility, Euler's theory of buckling, prediction of fiber properties by statistical methods (Weibull distribution) Unit V Fiber-reinforced composites, Metal-matrix composites, Ceramic matrix composites, Carbon-carbon composites, Manufacturing/processing methods, Structure-property relationship, and their applications in Defence.			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Understand the basics of composites and terminologies CO-2: Learn the origin of mechanical strength in materials CO-3: Understand the basic concepts of composite mechanics CO-4: Learn about the different fiber manufacturing processes and their properties CO-5: Recognize various composite manufacturing techniques and their applications			
Text Books			
• <i>Corrosion: Environment and Industries, Metals Handbook, Vol. 13c, Park Ohio, 1984, 10th Ed., ASM Metals, Ohio, 1987.</i> • <i>N.D. Tomashov, Theory of Corrosion and Protection of Metals, Macmillan, 1967.</i> • <i>M.G. Fontana, Corrosion Engineering, 3rd Ed., McGraw-Hill, 1985.</i> 4. <i>H.H. Uhlig, Corrosion & Corrosion Control, Wiley, 1985.</i>			

Reference Books
• <i>R. Lambourne and T.A. Strivens, Paint and Surface Coatings, Ellis Horwood D, Chichster, 1987.</i> • <i>C.G. Munger, Corrosion Prevention by Protective Coatings, NACE Pub., Houston, 1984.</i> • <i>Surface Finishing, Cleaning & Coatings, ASM Handbook, Vol. 5, 1994.</i> • <i>J. Biesiek and J. Weber Portcullis, Electrolytic and Chemical Conversion Coatings, Red Hill Press, 1976.</i> • <i>F.A. Lowenheim, Electroplating: Fundamentals of Surface Finishing, McGraw-Hill, New York, 1978.</i>

Course Code	Course Name	L – T – P	Credits
MM 626	Advanced Coatings	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the fundamentals of surface defects and surface engineering • Understand the types and functions of protective coatings • Explore the composition and formulation of paint coatings • Develop practical knowledge of coating application techniques • Apply coating technologies to real-world infrastructure			
Course Contents Unit I Surface defects and introduction to mitigation. Theory of surface reconstructions, electronic properties of surfaces, interfaces and overlayers. Characterization of surfaces by photons, electrons and ions as probes. Requirement of protective coatings, classification of organic, polymeric and inorganic coatings, conversion coatings, metallic coatings, electrodeposition and electroless coatings. Unit II Paint coatings for corrosion protection, role of resins, pigment, additives and solvents. Unit III Application techniques: Surface preparation and its importance in coating, role of coating selection & design of coating, failure mechanism, maintenance coatings, industrial paint systems, modern paint coating systems and specific examples. Unit IV Coatings for underground pipelines, storage tanks, overhead pipelines, offshore structures, ship hulls, risers, reinforced bars and concrete structures. Testing and evaluation. TBC, EBC Unit V Case studies			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Recognized requirements of protective coatings and their classification CO-2: Reviewed commonly used coating methods CO-3: Conception of coating application of material surface CO-4: Understanding importance of coating to underground surfaces, offshore structures, etc. CO-5: Case studies on advanced coating application			
Text Books			
• <i>R. Lambourne and T.A. Strivens, Paint and Surface Coatings, Ellis Horwood D, Chichster, 1987.</i> • <i>C.G. Munger, Corrosion Prevention by Protective Coatings, NACE Pub., Houston, 1984.</i>			
Reference Books			
• <i>Surface Finishing, Cleaning & Coatings, ASM Handbook, Vol. 5, 1994.</i>			

- *J. Biesiek and J. Weber Portcullis, Electrolytic and Chemical Conversion Coatings, Red Hill Press, 1976.*
- *F.A. Lowenheim, Electroplating: Fundamentals of Surface Finishing, McGraw-Hill, New York, 1978.*

Course Code	Course Name	L – T – P	Credits
MM 627	Surface Science and Engineering	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce the theoretical foundations of surface science • Understand how substrate surface structure influences overlayer behaviour • Examine surface phenomena at solid-liquid and solid-gas interfaces • Analyze different wear mechanisms and explore surface modification techniques • Explore advanced surface engineering techniques			
Course Contents Unit I Theory of surface reconstructions, electronic properties of surfaces, interfaces and overlayers. Characterisation of surfaces by photons, electrons and ions as probes. Unit II The effect of substrate surface structure on the overlayer properties. Theoretical and experimental evaluation of surface energies Unit III Solid-liquid and solid-gas interfaces-surface potentials, colloids, sedimentation, adsorption and reaction on surfaces. Damage of the surfaces by corrosion and wear. Unit IV Wear mechanisms and categories of wear. Surface modifications by diffusion, heat treatment and by coatings, Surface Processing laser, electrons and ions Unit V Physical and vapour deposition, CVD, ion-implantation, thermal spray coating.			
Course Outcomes After completing this course, the students will be able to: CO-1: Represented theory of surface reconstructions and its characteristics CO-2: Learn the effect of theoretical and experimental evaluation of surface energy of substrate surface structure CO-3: Demonstrate thermodynamics of solid liquid and solid gas interfaces CO-4: Analyzed wear mechanisms and their categorization CO-5: Fundamentals and applications of surface coating techniques			
Text Books • <i>M. Prutton, Surface Physics, 2nd Ed., Clarendon Press, Oxford, 1983.</i> • <i>A.W. Adamson, Physical Chemistry of Surfaces, 3rd Ed., Wiley, 1976.</i>			
Reference Books • <i>K.G. Budinski, Surface Engineering for Wear Resistance, Prentice-Hall, 1988.</i> • <i>K.H. ZumGahr, Microstructure and Wear of Materials, Elsevier, 1987.</i>			

Course Code	Course Name	L – T – P	Credits

MM 628	Reliability Engineering	3-0-0	3
Course Objectives: The primary objectives of this course are to: • Introduce fundamental probability and statistical tools • Understand and apply Failure Mode and Effect Analysis (FMEA) • Develop the ability to design and analyze experiments • Explore legal and strategic aspects of product design • Gain a comprehensive understanding of the product development process			
Course Contents Unit I Basic Probability Theory Basic concepts, Rules for combining Probabilities of events, Failure Density and Distribution functions, Bernoulli's trials, Binomial distribution, Expected value and standard deviation for binomial distribution – Examples Unit II Failure Mode and Effect Analysis (FMEA) Basic Principles and General Fundamentals of FMEA Methodology Unit III Design of Experiments Analysis of Variance Technique-Strategy of Experimental Design Unit IV Product Liability and Planning History, Product Safety Law, Product Liability Law, The future of product Liability- Prevention. Degree of Novelty of a Product, Product Life Cycle, Company Goals and Their Effect. Solution Finding Methods- Conventional Methods, Intuitive Methods, Discursive Methods, Methods for Combining Solutions- Examples. Unit V Product Development Process General Problem-Solving Process- Flow of Work During the Process of Designing, Activity Planning, Timing and Scheduling, Planning Project and Product Costs, Effective Organization Structures- Interdisciplinary Cooperation, Leadership and Team Behaviour.			
Course Outcomes			
After completing this course, the students will be able to: CO-1: Detailed overview of probability theory CO-2: Assessed fundamentals of FMEA techniques CO-3: Inspected Design of Experiments analysis of variance technique CO-4: Investigated future of product liability CO-5: Cognizance of product development and its application			
Text Books			
• <i>G. Haribaskaran, Probability, Queuing Theory & Reliability Engineering, Laxmi publications, Second Edition.</i> • <i>D. H. Besterfield, Glen H. Besterfield and M. Besterfield-Sacre, Total Quality Management, Pearson Publications, Third Edition</i>			
Reference Books			
• <i>E. Walpole, H. Myers and L. Myers, Probability and Statistics for engineering and Scientists, Pearson Publications, Eighth Edition.</i> • <i>BrendBretsche, Reliability in Automotive and Mechanical Engineering, Springer Publications.</i> • <i>G. Pahl, W. Bietz, J. Feldhusen and K. H. Grote, Engineering Design a Systematic approach, Springer Publications, Third Edition.</i> • <i>V. Sankar, System Reliability Concepts, Himalaya Publishing House, 2015.</i> • <i>Roy Billinton and Ronald N. Allan, Reliability Evaluation of Engineering Systems, Reprinted in India B. S. Publications, 2007.</i> <i>E. Balagurusamy, Reliability Engineering, Tata McGraw-Hill, 200</i>			

School of Energy & Environment

M.Sc. Food Technology

DEPARTMENT OF APPLIED CHEMISTRY

M.Sc. Food Technology
Revised Programme Structure as per National Education Policy (NEP) w.e.f.
July 2025
Department of Applied Chemistry, DIAT In association with DIBT, Mysore

PROGRAMME STRUCTURE w.e.f. 2025-2027 Batch			
Sr. No	Code	SEMESTER I	Credit
1	ACFT 501	Food Chemistry	4
2	ACFT 502	Principles of Food Processing and Preservation	4
3	ACFT 503	Food and Nutrition	3
4	ACFT 504	Food Microbiology	3
5	RM501	Research Methodology	4
6	ACFT 512	Laboratory (PSL)	2
		Total Credit of Semester I	20

Sr. No	Code	SEMESTER II	Credit
1	ACFT 521	Food Analysis & Sensory Evaluation	4
2	ACFT 522	Food Standards and Safety Management	3
3	PE-I	ELECTIVE -I	3
4	PE-II	ELECTIV -II	3
5	PE-III	ELECTIVE -III	3
6	OJT	On Job Training /(Intern / Project (120 hours)	4
		Total Credit of Semester II	20

LIST OF ELECTIVES FOR SEMESTER II			
1	ACFT 523	Technology of Fermented Foods	3
2	ACFT 524	Military Nutrition	3
3	ACFT 525	Technology of Milk & Dairy Products	3
4	ACFT 526	Functional and Personalized Nutrition	3
5		Electives from App Chem Dept or another dept with equal credit	3
6		Elective from NEPTL	3

Sr. No	Code	SEMESTER III	Credit
1	ACFT 531	Fundamentals of Food Engineering	4
2	ACFT 532	Technology of Fruits, Vegetables and Plantation Crops	3
3	PE-IV	ELECTIVE -IV	3
4	PE-V	ELECTIV -V	3
5	PE-VI	ELECTIVE –VI	3
6	RP541	Project I	6
		Total Credit for Semester-III	22

LIST OF ELECTIVES SEMESTER III			
	ACFT 533	Technology of Cereals, Pulses and Oil Seeds	3
	ACFT 534	Technology of Meat, Poultry & Fish Processing	3
	ACFT 535	Food Packaging Technology	3
	ACFT 536	Advanced Food Technology	3
		Electives from App Chem Dept or another dept with equal credit	3
		Elective from NEPTL	

Sr. No	Code	SEMESTER IV	Credit
1	RP 542	Project -II	18
		Total Credit for Semester-IV	18

SEMISTER-I

COURSE CODE	COURSE NAME	CREDITS
ACFT 501	FOOD CHEMISTRY	4
Unit-1. General Introduction & scope: Fundamentals of Chemistry, Physico-chemical and functional properties of various food constituents and importance. Unit-2. Water: Physical and chemical properties of Water and Ice, water activity, Dispersed systems and surface phenomena. Unit-3. Carbohydrates-Classification, structure, sources, Physico-chemical, functional properties of sugars and polysaccharides in foods& their applications. Unit-4. Proteins and amino acids: Classification, structure, sources, physico-chemical, functional properties of proteins & amino acids. Enzymes (classification, mode of action, kinetics, assay techniques, isolation and purification and applications). Denaturation of proteins. Principles for separation methods. Protein concentrates and isolates. Processing induced physical and chemical changes in Proteins. Unit-5. Lipids: Classification, structure, sources, physico-chemical, functional properties of lipids. Rancidity, Fatty acids- saturated mono unsaturated and poly-unsaturated. Chemistry of fats and oil and their role. Modifications of lipids. Unit-6. Vitamins and Minerals: Classifications, biological importance and functions, dietary sources, deficiency diseases, recommended dietary allowance.		
COURSE CODE	COURSE NAME	CREDITS
ACFT 502	PRINCIPLES OF FOOD PROCESSING AND PRESERVATION	4
Unit-1. Introduction: Definition and scope of Food Science and Technology, historical development of food processing and preservation, general principles of food preservation, unit operations, effect of various food processing operations on nutrients, packaging materials used for foods. Unit-2. Preservation by heating: Principles of the method, Types of microorganisms, bacterial load, sterilization and commercial sterility, thermal resistance of the microorganisms and enzymes. Canning and bottling, ultra-high temperature processes, determination of thermal process time.		

Unit-3. Refrigeration and freezing preservation: Refrigeration, refrigerated storage of various foods, freezing of foods, influence of freezing and freezing rate of the quality of food products, methods of freezing, storage and thawing of frozen foods. Unit-4. Drying and dehydrations: Water activity and its effect on the keeping quality, sorption isotherms. Factors affecting drying, methods of drying, type of driers, intermediate moisture foods. Unit- 5. Newer methods of food preservation: Introduction, newer thermal and non-thermal methods, irradiations, principles, applications in food processing. Unit-6. Chemical preservation: Preservation of foods using sugar, salt, chemicals, smoking		
COURSE CODE	COURSE NAME	CREDITS
ACFT 503	FOOD AND NUTRITION	3
Unit-1. Introduction to Nutrition: Nutritive value of food, recommended dietary allowance, interrelationship between nutrients, nutritional aspects of carbohydrates, lipids, proteins, vitamins, minerals, fibre, water and electrolyte balance, digestion and absorption of food, energy value of foods, and energy requirements for various conditions, nutrition of infants, children's, adolescents, mother and geriatric nutrition, high altitude nutrition. Military nutrition. Unit-2. Nutritional Requirements & Disease Control: Therapeutic nutrition & formulation of special dietary foods; Relation of food and diseases; Deficiencies of essential nutrients; Assessment of nutritional status & RDA; Effect of processing on nutrients; Functional foods with attributes to control cardiovascular diseases, cancer, obesity, ageing etc., Unit-3. Nutrition of dietary fibres. Biological value of proteins. Energy value of foods. Techniques of diet and health surveys. Formulation of diets and food products for specific needs. Unit-4. Introduction to nutraceuticals: definitions, synonymous terms, basis of claims for a compound as a nutraceutical, regulatory issues for nutraceuticals.		
Course Code	Course Name	Credits
ACFT 504	Food Microbiology	3
Unit-1. Introduction to Microbiology: Historical developments; food microbiology basics and scope; structure, growth & reproduction of bacteria, yeast, fungi, algae and viruses - A brief account. Unit-2. Microbial growth factors and food spoilage - Intrinsic and extrinsic parameters affecting microbial growth; cultivation of microorganisms; different types of spoilage and their control for various foods. Unit-3. Microbial detection and destruction- sample collection, transport and storage; sample preparation for analysis; microscopic and culture dependent methods for microbial detection; thermal death time, Z, F and D values; principles of food preservation; control of water activity.		

Unit-4. Food hygiene, sanitation and public health: Contamination during handling and processing and its control; indicator organisms; Rapid methods in microbial detection; food poisoning- types and significance; bacterial agents of food borne illness; non-bacterial agents of food borne illness - poisonous algae, fungi and food borne viruses - A brief account.

Course Code	Course Name	Credits
ACFT 512	Laboratory Experiment (Any 12)	2
1. Principles and working of common analytical instruments. 2. Analysis of water with respect to pH 3. Determination TDS of water 4. Determination of total hardness of water 5. To determine the moisture content in the given sample 6. To determine the total ash content in the given sample 7. To determine the acid insoluble ash in the given sample 8. Estimation of reducing and non-reducing sugars, starch 9. Estimation of vitamin-C 10. Analysis of lipids-saponification value 11. Determination of TSS, pH, acidity 12. determination of acid value and free fatty acids of given oil/ fat sample 13. Principles and working of common instruments including microscopy. 14. Preparation of nutrient media, sterilization and inoculation techniques 15. Staining techniques: Monochrome staining, gram staining, acid fast staining, spore staining, capsule staining and motility of bacteria. 16. Pure culture techniques: isolation of pure cultures from spoiled food 17. Growth characteristics: Methods for determination of microbial numbers– direct and plate count; Generation time. 18. Industrial Visit		

SEMISTER-II

Course Code	Course Name	Credits
ACFT 521	Food Analysis and Sensory Evaluation	4
Unit-1. Food Component Analysis: Proximate composition includes protein, fat, moisture ash etc. Analysis of minerals & vitamins & nutritional component, pesticide analysis. Use of Analytical Techniques in Food Science; Basics, Principles and Applications of UV – Vis Spectrophotometer, Gas Chromatography (GC),		

High Pressure Liquid Chromatography (HPLC), LCMS, GCMS, Atomic Absorption Spectroscopy (AAS), ICPMS, MALDI-TOF, Fourier Transform Infrared Spectroscopy (FTIR), Differential Scanning Calorimetry (DSC) and Thermo Gravimetric Analysis (TGA). Microwave and IR techniques.

Unit-2. Introduction to quality attributes of food: Appearance, flavour, textural factors and additional quality factors. Chemical dimensions of basic tastes- sweet, salt, sour, bitter and umami

Unit-3. Gustation & Taste perception: Structure and physiology of taste organs- tongue, papillae, taste buds, salivary glands. Mechanism of taste perception Factors affecting taste quality& evaluation methods for sensory analysis, Estimation of colour of food by visual /instrumental means.

Unit-4. Principles and working of common instruments.

Practical

1. Analysis of minerals by using Atomic Absorption Spectroscopy (AAS)/ICP
2. Fatty acid analysis by using GC
3. Determination of vitamins by chromatography
4. Taste evaluation
5. Evaluation of Taste thresholds
6. Taste evaluation by overall acceptability (OAA)

Course Code	Course Name	Credits
ACFT 522	Food Standards and Safety Management	3

Unit-1. Importance and functions of food safety and quality control: Concept and meaning of food quality and food Safety, food adulteration, food hazards.

Unit-2. Food laws and regulations – International and National scenario & law, standards and governing bodies dealing with inspection, certification, traceability and authentication such as Codex Alimentarius Commission, USFDA, FSSAI, Voluntary national standards (BIS and AGMARK). Domestic regulations and Food Safety and Standards Act, 2006

Unit-3. Principles of Food safety and quality management- Total Quality Management, Risk analysis (risk management, risk assessment and risk communication), History, structure, principles, HACCP applications, HACCP based SOPs, Other food safety practices (GMP/GHP; GLP, GAP sanitary and hygienic practices)

Unit-4. Food Safety and Quality Management Systems-Quality Management system (ISO-9001), food safety management system (ISO 22000:2005 and ISO 22000:2018). Quality manuals, documentation and audits, case studies of food safety and Quality management. Quality assurance and quality control, sampling procedures and plans, specification of raw materials and finished products, labelling issues, export import policy; laboratory quality procedures and assessment of laboratory performance

ELECTIVE SUBJECTS FOR SECOND SEMESTER

Course Code	Course Name	Credits
ACFT 523	Technology of Fermented Food	3
Unit-1. Scope and Importance: History and Introduction to fermentation Technology, Types of Fermentation, Fermentor Designs. Unit-2. Fermentation process: Media formulations, sterilization, Starter cultures and their maintenance. Factors influencing fermentation process. Down-stream process. Immobilization of enzymes. Primary and secondary metabolites Fermented food products: Lactic acid fermentation. Ethanol fermentation. Vitamin B-12 fermentation. Fermented Dairy products. Wine and Beer fermentation. Vinegar fermentation. Bread making by yeast. Indian traditional foods, pickles, fermented vegetables, Mushroom cultivation, Oriental fermented products, Probiotics. Unit-3. GM foods: Genetically modified microorganisms and foods. Bio-safety, ethics and risk assessment Unit-4. Valorization of Agri food waste: Bioethanol production, biohydrogen production. Practical 1. Media preparation and sterilization 2. Fermentation involving lactic acid bacteria. 3. Identification of simple secondary metabolites such as lactic acid bacteriocins.		
Course Code	Course Name	Credits
ACFT 524	Military Nutrition	3
Unit 1. Introduction to Military Nutrition Definition and scope of military nutrition, Differences between civilian and military nutrition needs, Nutritional challenges in various military settings (combat, training, deployment) Unit 2. Human Physiology and Energy Systems in Military Performance -Basic human metabolism and energy systems, Role of macronutrients in energy production, Role of micronutrients for physical and cognitive performance, Hydration and electrolyte balance in high-stress environments Unit 3. Nutritional Needs for Different Military Populations Nutrition for different branches of the military (Army, Navy, Air Force, Marines), Energy and macronutrient requirements for different military roles (infantry, pilots, special forces), Gender-specific nutritional considerations, Dietary needs for high-altitude, cold weather, desert, and jungle operations.		

Unit 4: Meal Planning, Military Rations and performance nutrition for military training and combat-

Types of military rations (MREs, First Strike Rations, Unitized Group Rations), Nutritional composition and adequacy of military field rations, Pre-mission and post-mission nutrition strategies, Nutritional supplements for military performance and resilience and recovery

Unit 5: Mental Performance, Emergency Survival and Rehabilitation Nutrition -

Nutritional impact on cognitive function, alertness, and decision-making, Strategies to prevent fatigue, sleep deprivation effects, and combat stress through diet, Emergency nutrition strategies for survival situations, Role of protein and micronutrients in muscle repair and wound healing, Anti-inflammatory diets and functional foods for injury recovery

Course Code	Course Name	Credits
ACFT 525	Technology of Milk and Dairy Products	3

Unit-1. Introduction: Present status of milk & milk products in India and Abroad; market milk- Composition of milk of various species, quality evaluation and testing of milk, procurement, transportation and processing of market milk, standardization, toning of milk, homogenization, pasteurization, sterilization, storage, transportation and distribution of milk. Cleaning & sanitization of dairy equipment's. Special milks such as flavoured, sterilized, recombined & reconstituted toned & double toned. Judging and grading of milk and its products.

Unit-2. Condensed milk- Definition, methods of manufacture, evaluation of condensed & evaporated milk; dried milk- Definition, methods of manufacture of skim & whole milk powder, instantization, physiochemical properties, evaluation, defects in dried milk powder.

Unit-3. Butter- Definition, composition, classification, methods of manufacture, theories of churning, evaluation, defects in butter.

Unit-4. Ice cream- Definition, composition and standards, nutritive value, classification, methods of manufacture, evaluation, defects in ice cream,

Unit-5. Cheese: Definition, composition, classification, methods of manufacture, cheddar, Gouda, cottage and processed cheese, evaluation, defects in cheese.

Unit-6. Milk product processing khoa, channa, paneer, fermented milk products. Yoghurt, dahi- Drying Theories, Dried milk: Definition and composition, production by drum drying and air spray system; defects; dried milk products–butter-milk powder, whey powder, cream powder, infant milk food. Drying Equipment's: Spray Drier, Drum Drier. Novel emerging milk processing techniques. Quality Control in Milk Processing: Tests for evaluation of quality of milk and adulteration.

Practical

1. Study on basics of reception of milk at the plant; platform test of milk, physico-chemical, microbiological and sensory analysis of milk and milk products
2. Estimation of fat by Gerbers' method and SNF in milk;
3. Homogenization of milk.
4. Preparation of special milks;
5. Preparation and evaluation of table butter,
6. Determination of adulterants in milk-by-milk testing kit.

Course Code	Course Name	Credits
ACFT 526	Functional and Personalized Nutrition	3
Unit 1: Introduction to Functional & Personalized Nutrition-Definition and scope of functional and personalized nutrition, Differences between traditional, functional, and personalized diets, Role of functional foods in disease prevention and health optimization. Unit 2: Functional Foods and Bioactive Compounds-Classification of functional foods: probiotics, prebiotics, polyphenols, omega-3s, fiber, Mechanisms of action of bioactive compounds Unit 3: Development of Functional Foods for Specific Health Conditions-Cardiovascular Health: Omega-3s, plant sterols, fiber, Gut Health: Probiotics, prebiotics, fermented foods, Diabetes Management: Low-GI foods, resistant starch, dietary fibers, Cognitive Function: Nootropics, flavonoids, MCTs, Sports Nutrition: Protein optimization, amino acids, ergogenic aids Unit 4: Smart wearables for real-time nutritional tracking- Nutrigenomics-based meal planning apps, Role of microbiome analysis in precision nutrition		

SEMISTER-III

Course Code	Course Name	Credits
ACFT 531	Fundamentals of Food Engineering	4
Unit-1. Fundamental Concepts and Definitions: Introduction to food engineering, Dimensions and units, thermodynamic systems (closed, open and isolated), intensive and extensive properties, equilibrium state, density, specific volume, specific weight, specific heat, enthalpy, entropy, pressure, temperature scales. Material Balances: Principles, process flow diagrams, total mass balance, component mass balance, material balance problems involved in dilution, concentration and dehydration; heat balance calculations. Energy Balances: Principles, energy terms, specific heat of solids and liquids, properties of saturated and superheated steam, heat balances. Unit-2. Heat Transfer Conduction: Fourier's law, thermal conductivity, resistances in series, heat flow through cylinder. Convection: Natural convection and force convection, film coefficient, overall heat		

transfer coefficients, dimensionless numbers – pandtl number and nusselt and heat transfer from condensing vapours to boiling liquids, heat exchange equipment applied to food insustries – jacketed pans, heaters, coolers – tubular heat exchangers, scrapped surface heat exchangers and plate heat exchangers.

Radiation: Stefan-Boltzmann constants. Black bodies. Irradiation of foods. Radiation units and doses for foods, safe limits, irradiation mechanism and survival curve, irradiation of packaging materials.

Thermal process calculations: Commercially sterile concept, concept of D, F and Z values, reference F value; effect of temperature on thermal inactivation of micro-organisms, thermal process calculation for canned foods; calculation of processing time in continuous flow systems. **Evaporation:** Properties of liquid, heat and mass balance, single and multiple effect evaporation, steam economy, heat recovery, efficiency, process calculations, equipment, accessories and systems. Application of evaporators in food industries.

Unit-3. Mechanical operations: Mixing kneading, and blending: solid mixing, liquid mixing, classification of equipment and application. Homogenisation. **Size separation:** filtration theory, constant rate and constant pressure filtration. Classification of filtration equipment – plate and frame filter press, rotary vacuum filters, leaf filters, centrifugal filters and air filters. Sedimentation – sedimentation of solids in liquid and solids in gas – stokes law, centrifugal separation – equipment and theory. **Size reduction and classification:** Slicing, dicing, crushing and grinding – laws governing crushing and grinding – classification of equipment and applications. Sieve analysis, standard sieves – types of equipment, vibrating screen, tromels, oscillating, vibrating and planetary equipment. **Extrusion Cooking:** Theory and applications, extrusion cookers and cold extrusion, single and twin screw extruders, design considerations.

Unit-4. Distillation : Vapour-liquid relationships, Raoult's law, Henery's law,boiling point diagram, classification of distillation – batch distillation, steam distillation, vacuum distillation and rectification and their application to food industries. **Drying :** Theory and Mechanism of drying, moisture and drying rate curves, free moisture content, critical moisture content, equilibrium moisture content, constant and falling rate periods, spray, drum, bin, cabinet, tunnel, vacuum shelf dryer, through flow dryer, fluidized bed dryers, batch and continuous operational, osmotic dehydration, freeze drying and their respective applications in food industries. **Chilling, refrigeration and freezing:** Shelf life extension requirements for various products, theories, characteristics curve, cooling rate calculations. Chilling and freezing equipment, cryogenics. Freezing – technological principles of freezing operations, freezing systems – direct contact and indirect contact system; influence of freezing rate on food system; freezing time calculations. **Crystallization:** Solubility, nucleation, super saturation, heat of crystallization, type of crystallization, equipment and applications

Practical's

1. Mechanical drawing

2. Refrigeration plant
3. Boiler house
4. Pilot plant
5. Electrical laboratory
6. Instrumentation
7. Pumps and Flow meters
8. Mass and energy balance
9. Determination of water activity
10. Heat treatment pasteurization and sterilization
11. Thermal Process calculations
12. Canning operations
13. Dehydration of fruits and vegetables – drying rate curves
14. Numerical Problem based on Mass balance
15. Size determination
16. Mixing, kneading, blending
17. Extrusion products
18. Filtration and centrifugation
19. Freezing curve
20. Filtration and centrifugation
21. Freezing curve

Course Code	Course Name	Credits
ACFT 532	Technology of Fruits, Vegetables & Plantation Crops	3
Unit-1. Introduction to fruits and vegetables: Importance of fruits and vegetables; structure, classification and general composition of fruits and vegetables, Indian and global scenario on production and processing of fruits and vegetables Unit-2. Postharvest handling, storage of fresh fruits and vegetables: Post-harvest changes in fruits and vegetables, climacteric rise, horticultural maturity, physiological maturity, physiological changes during ripening and storage of fruits and vegetables, factors affecting postharvest losses. Fresh fruits and vegetables handling, sorting, grading, Phyto sanitation, cooling, packaging, quality assurance, chilling injury. Principles of storage, types of storage, low temperature storage, modified atmosphere and controlled atmosphere storages, hypobaric storage. Unit 3. Processing of fruits and vegetables: Canning of fruits and vegetables, syrups and brines for canning, types of cans, manufacturing of cans, lacquering, mechanical defects, spoilage in canned foods. Fruit juices, beverages and concentrates, carbonated beverages, fruit juice powders. Jams, jellies, marmalades, preserves and candied products, role of pectin, theory of jelly formation, strength of pectin. Chutneys, sauces, pickles and tomato products.		

Unit 5: Plantation crops: Importance of plantation crops, chemical composition, processing of tea, coffee, cocoa, chicory. Spices, production, processing.

Practical's

1. Equipment for fruits and vegetable processing and plant layout
2. Preparation of fruit juices, squashes, syrups and ready-to-serve beverages
3. Preparation of jams, jellies, marmalades,
4. Canning of fruits and vegetables
5. Estimation of pectin, Estimation of browning enzymes, PPO and POD
6. Determination of salt content

ELECTIVE SUBJECTS FOR THIRD SEMESTER

Course Code	Course Name	Credits
ACFT 533	Technology of Cereals, Pulses and Oil Seeds	3
Unit-1. Wheat and wheat processing: Structure, types and physicochemical characteristics; wheat milling products and by products; factors affecting quality parameters; physical, chemical and rheological tests on wheat flour; manufacture of bakery products confectionary products and other cereal-based foods. Unit-2. Rice and rice processing- Structure, classification, physicochemical characteristics; cooking quality; rice milling technology; by- products of rice milling and their utilization; Parboiling of rice-technology and effect on quality characteristics; aging of rice - quality changes; processed products based on rice. Unit-3. Maize and maize processing: Structure, Classification, chemical properties. Primary and secondary processing products. Application in food and allied industries. Unit-4. Millets and millet processing: Structure, etc. Types & availability, Post-harvest processing handling & storage. Millet based primary and secondary processed products. Unit-5. Bakery and confectionary industry; raw materials and quality parameters; dough development; methods of dough mixing; dough chemistry; rheological testing of dough. Technology for the manufacture of bakery products and the effect of variations in formulation and process parameters on the quality of the finished product; Staling and losses in baking; machineries used in bakery industry. Chapati making process and qualities, Unit-6. Legumes, pulses and their processing: Type of legumes/pulses, physicochemical and nutritional characteristics, processing and value-added products, storage. Oil seeds and their processing: Production of edible oils and other by-products. Refining of edible oils; Hydrogenation and value added products. Practical:		

1. Physical characteristics of grains
2. Texture analysis of grains
3. Oil extraction from oilseed
4. Oil content of oilseeds
5. Free fatty acids, Iodine value
6. Saponification value
7. Peroxide Value
8. Estimation of gluten content,

Course Code	Course Name	Credits
ACFT 534	Technology of Meat, Poultry And Fish Processing	3
Unit-1. Meat: Sources of meat and meat products in India, its importance in national economy. Selection of animals for slaughtering, importance of traceability, ante-mortem inspection, grading and safety protocols. Effect of feed, breed and management on meat production and quality. Chemical composition and muscle structure, post-mortem muscle chemistry; meat colour and flavours; meat microbiology and safety. Modern abattoirs/ meat plants, typical layout and features, design of Ante-mortem handling facilities; hoisting rail and travelling pulley system; stunning methods; Slaughtering of animals and poultry. Steps in slaughtering and dressing; offal handling and inspection; inedible by-products; operational factors affecting meat quality: Rigor mortis, pH changes, colour changes, effects of processing on meat tenderization; abattoir equipment and utilities. Meat quality evaluation, inspection, grading of meat. Mechanical deboning, Meat plant sanitation and safety Chilling and freezing of carcass and meat/poultry; factors responsible for effective chilling and freezing, importance of cold chain facilities, quality changes during chilling and freezing, cold shortening, ripening, DFD and PSE, Factors affecting post-mortem changes - properties and shelf-life of meat. Processing of meat – pickling, curing and smoking; thermal and non-thermal processing methods of preservation – retort processing, different dehydration techniques, high pressure processing, hurdle processing and irradiation. Unit-2. Poultry: classification, composition, preservation methods and processing. Poultry industry in India, quality characteristics of poultry products, microbiology of poultry meat, spoilage factors; Layout and design of poultry processing plants, Plant sanitation; Poultry meat processing operations, equipment used – Defeathering, bleeding, scalding etc.; Packaging of poultry products, refrigerated storage of poultry meat and by-products		

Structure, composition, nutritive value and functional properties of eggs and its preservation by different methods. Processing of egg products. Factors affecting egg quality and measures of egg quality. Packaging of eggs, egg products,

Unit-3. Fish: Types of fish, composition, structure, post-mortem changes in fish. Handling of fresh water fish. Canning, smoking, freezing and dehydration of fish. Preparation of fish products, fish sausage and home makings. Commercially important marine products from India; product export and its sustenance; basic biochemistry and microbiology; transportation in refrigerated vehicles; deodorization of transport systems; design of refrigerated and insulated trucks; grading and preservation of shell fish; pickling and preparation of fish protein concentrate, fish oil and other by-products.

Practical

1. Slaughtering and dressing of meat animals;
2. Study of post-mortem changes;
3. Meat cutting and handling; evaluation of meat quality;
4. Preservation by dehydration, freezing, canning, curing, smoking and pickling of fish and meat;
5. Evaluation of quality of eggs;
6. Estimation of meat: bone ratios;
7. Application of meat testing kits for quality evaluation.
8. Visit to meat processing plants / modern abattoir

Course Code	Course Name	Credits
ACFT 535	Food Packaging Technology	3

Unit-1. Introduction to food packaging: Definition, objectives, functions and roles of food packaging, Packaging design and development, Packaging environment, Factors influencing the selection of packaging. **Packaging materials and their properties:** Paper: pulping, fibrillation and beating, types of papers, paper boards, corrugated fibre board, Glass: composition, properties, types of closures, methods of bottle making; Metals: types of cans, tin and aluminium based cans, lacquers; Plastics: used in packaging, their chemical structure and properties. **Different forms of packaging:** Rigid, semi rigid and flexible, Liquid and powder filling machines; bottling machines, Form fill seal and multilayer aseptic packaging machines, vacuum packs unit, shrink pack unit, tetra-pack unit

Unit-3. Testing of packaging materials: Mechanical properties such as tensile strength, bursting strength, tearing resistance, puncture resistance, impact strength, tear strength, bond strength, heat seal strength, Cobbs value, their methods of testing and evaluation. **Barrier properties of packaging materials:** Theory of permeability, factors affecting permeability, permeability coefficient, gas transmission rate (GTR) and its measurement, water vapour transmission rate (WVTR) and **Migration from packaging materials:** Overall and specific migration, physical process, partition coefficient and sorption process, determination

of migration, food simulants, packaging flavour interaction, factors affecting flavour absorption, role of food matrix.

Unit-4. Recent trends in food packaging: Vacuum packaging, controlled atmospheric packaging (CAP), modified atmospheric packaging (MAP), gas packing, bioplastics in food packaging, aseptic packaging, retort pouch packaging, microwave packaging, active packaging, intelligent packaging, smart packaging, edible packaging, shrink and stretch packaging. **Packaging systems and methods:** Packaging requirements and their selection for raw and processed foods, dehydrated foods, frozen foods, cereals and pulses, fats and oils, dairy products, beverages, fresh fruits and vegetables, meat, poultry and sea foods.

Unit-5.Role of packaging in food marketing: Coding and marking; nutrition labelling, Traceability: RFID tag, bar coding, QR code. **Packaging Laws and regulations:** safety aspects of packaging materials, Environmental & recycling and waste disposal.

Practical

1. Identification and testing of packaging materials
2. Determination of grammage, water proofness
3. Determination of physico-mechanical properties (thickness, tensile properties, tear strength and seal strength) of polymer packaging materials
4. Determination of total migration
5. Determination of water vapour transmission rate (WVTR) and gas transmission rate (GTR) of packaging material
6. Determination of gas composition by Head space analyser

Course Code	Course Name	Credits
ACFT 536	Advanced Food Technology	3

Unit-1. Introduction: Scope and importance of advanced techniques in food technology, Importance and types of thermal and non-thermal processing techniques.

Unit-2. Dielectric heating, Microwave heating, Infrared heating, Combination processing, RF heating, Ohmic heating, Extrusion cooking (Introduction, processing equipment and design, Mode of action, Biological effect and application in food processing)

Unit-3. High hydrostatic pressure in food processing, High intensity pulsed electric field processing, High pressure CO₂ processing, O₃ (Ozone) processing, Electron beam processing, Pulsed light processing, Ultra sonication. processing, (Introduction, processing equipment and design, Mode of action, biological effect and application in food processing)

Unit-4. Application of nanotechnology in food systems, Introduction and applications in foods, human nutrition, preservation, processing, packaging.

SEMISTER-IV

Course Code	Course Name	L – T – P	Credits
RP 542	PROJECT -II		18

*M.Sc. in Materials
Science*

M. Sc. in Materials Science

Brief Description:

The Department of Metallurgical and Materials Engineering aims to develop a core competence in teaching and research in the areas of Materials Science/Engineering and its applications to defence technologies and products. Being a Defence University, the department offers M. Tech and Ph. D. programs in materials engineering and is also engaged in conducting various short-term courses for DRDO and Defence officers. The main focus of our research is to investigate the structure-property-performance relationship of various materials for Defence applications. To cater to the defence need further, the department offers M.Sc. program in Materials Science for B.Sc. graduates.

This program is offered for DRDO employees and officers from Tri-services, defence public sector undertaking, ISRO/DAE personnel, industry personnel, faculty members from institutes/universities, and civilian students. This program is also open to friendly foreign countries.

At present, the Department is equipped with major characterization facilities (few instrument names are mentioned below) such as:

- High Resolution Transmission electron microscope (TEM) with STEM, Lorentz, HAADF and EDAX facilities
- Field emission scanning electron microscope (FESEM) with EDS
- Small angle x-ray scattering (SAXS)
- Physical Property Measuring System (PPMS)
- Wear and friction measurement equipment
- Micro-Hardness Tester
- Brinell and Rockwell Hardness Tester
- Automatic grinding and polishing machines
- Optical polarizable microscope with image analyser
- Surface Area Analyzer
- Impedance Analyzer and Electrochemical workstation
- Piezometer
- Corona Poling Unit
- UV-Visible Spectroscopy
- Contact Angle measurement unit

and many materials synthesis facilities also available in the Department such as:

- Spray Pyrolysis set-up
- High-Temperature Furnace
- Centrifuge
- Autoclave
- Vacuum Oven
- Orbital Shaker
- Twin screw extruder
- Plastography
- Two roll mill
- Hydraulic press

- Electro spinning unit
- Homogenizer
- Sonicator

The development of know-how and manufacturing technologies of many strategic and advanced materials like intelligent textiles, biosensors, electrospinning, magnetic materials, engineering adhesives, structural composites, hybrid supercapacitors, functional materials, biomaterials for prosthetics, tissue engineering, plastics processing, piezoelectric materials, supercritical foaming technology, additive manufacturing, friction stir processing/welding, crystallographic texture, high entropy alloys, computational materials, batteries etc., are taken up by the faculties and students. The Department is working on many sponsored research projects and the researchers have developed a range of products, including propellers for fuel cells, encapsulated drugs on fibers, magnetic alloys, inorganic oxides for drug delivery, encapsulation and sustained release of anti-cholesterol drugs, polymeric beads and membranes for toxic and heavy metal adsorption (effluent treatment), carbon foams for high-temperature applications and open cell polyurethane foams for automobile applications, development of Ti metal matrix composite, welding of additively manufactured alloys, development of high entropy alloys. Moreover, the Department participates extensively in R&D activities in collaboration with Defence Labs and Establishments of India. International collaborative work is being carried out with Naval Postgraduate School (NPS), California, Cranfield University, UK, Loughborough University, UK, National Ding Hwa University, Taiwan, Weizmann Institute of Science, Israel, etc.

Eligibility:

The eligibility for the M.Sc. postgraduate program is B.Sc./B.Sc. (Honors) or equivalent in any branch of science/mathematics or BE/B.Tech/BS in any branch of Engineering. Also, the student should have a mathematics subject in 12th standard.

Organization:

The program is of four-semester duration with minimum of 80 credits. The first semester is of 20 credits having research methodology as compulsory institutional credit course. The second and third semesters are 20 and 22 credits respectively. In both the semester 3 elective courses (in each semester) are added. Also, one “on job training (OJT)/field project (FP)” is included in second semester. In third semester research project of 6 credit is added. In the fourth semester, students will have to perform M.Sc. research project of 18 credits. There will be continuous evaluation in every semester which may comprise two assessments and a final examination for theory subjects. At the end of the final (fourth) semester, students will submit their thesis before going for final evaluation and present their M.Sc. project work before the expert committee (consists of External / Internal members from various R&D Organizations/Institutions / Universities, etc.). No credits are counted for attending an audit course.

Course structure for M.Sc. in Materials Science

Semester I

Sr. No.	Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
			L	T	P	
1	MS501	Structure and Properties of Materials	3	1	0	4
2	MS502	Materials Characterization Techniques	3	1	0	4
3	MS503	Thermodynamics, Kinetics, and Phase Transformations	3	0	0	3
4	MS504	Polymer Synthesis, Manufacturing, and Technology	3	0	0	3
5	MS505	Materials Laboratory	0	0	4	2
6	RM501	Research Methodology	4	0	0	4
		Total				20

Semester II

Sr. No.	Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
			L	T	P	
1	MS506	Processing of Metals and Ceramics	3	0	0	3
2	MS507	Polymer Processing and Rheology	3	1	0	4
3		Elective I	3	0/1	0/2	3/4
4		Elective II	3	0/1	0/2	3/4
5		Elective III	3	0/1	0/2	3/4
6	OJT/FP	On-Job Training/Field Project	0	0	8	4
		Minimum Total				20

Semester III

Sr. No.	Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
			L	T	P	
1	MS508	Functional Materials	3	1	0	4
2	MS509	Principles of Metallurgy	3	0	0	3
3		Elective IV	3	0/1	0/2	3/4
4		Elective V	3	0/1	0/2	3/4
5		Elective VI	3	0/1	0/2	3/4
6	MS541	Research Project 1	0	0	12	6
		Minimum Total				22

Semester IV

Sr. No.	Course Code	Subjects (Theory/Practical)	Contact Hours		Credits
			L	T/P	
1	MS542	Research Project 2	0	36	18

Total credit – 18

List of Electives

Sr. No.	Course Code	Name of the Course
Electives from the Department		
1	MS510	Non-destructive Testing
2	MS511	Polymer characterization and Testing
3	MS512	Corrosion and Mitigation
4	MS513	Nanoscience and Nanotechnology
5	MS514	Chemistry of Polymer
6	MS515	Additive Manufacturing of Materials

7	MS516	Biomaterials
8	MS517	Computational Mathematics
9	MS518	Computational materials Science
10	MS519	Polymer materials and composite blend

#Since, DIAT adopted choice-based credit system, student can choose any subject from the Institute (other Departments of DIAT) as well as from online platforms (NPTEL, MOOC, SWAYAM, etc.) as an elective subject. A maximum of 6 credits can be opted by student as professional electives from the list of online courses on NPTEL/SWAYAM during second and third semesters.

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS501	Structure and Properties of Materials	3	1	0	4
Course Objectives: - To introduce the basics of bonding and crystal structure of various crystalline materials - To enable the student to understand the structure and properties of ceramics - To introduce the electronic, magnetic, thermal and optical properties of the materials					
Unit I: Introduction, classification of materials; atomic structure, bonding in solids, bonding forces and energies; crystal structure, unit cells, crystal systems, crystallographic points, directions, and planes,					
Unit II: Crystalline and non-crystalline materials, anisotropy; Structure of crystalline solids: metallic crystal structure					
Unit III: Ceramic materials, Basic properties, classification of ceramic materials—conventional and advanced, ceramic crystal structure, Defects in ceramics: types of defects, origin of point defects, defects and electron energy levels, defect equilibria in ceramic crystals					
Unit IV: Electronic and Magnetic Properties: Free electron theory, Fermi energy, density of states, elements of band theory, semiconductors, Hall effect, dielectric behavior, piezo and ferro-electric behaviour, Origin of magnetism in materials, para-, dia-, ferro- and ferri-magnetism					

Unit V: Thermal and optical properties: Specific heat, heat conduction, thermal diffusivity, thermal expansion, and thermoelectricity, Refractive index, absorption and transmission of electromagnetic radiation, Examples of materials exhibiting the above properties, and their typical/common applications.

Course Outcomes

CO1: Understanding classifications and characteristics of materials

CO2: Analysis and properties of crystalline materials

CO3: Detailed overview of ceramics and their characteristics

CO4: Cognizance of dielectrics, refractories and their applications

CO5: Demonstration of Solid state, Sol-Gel, Hydrothermal and Co-precipitation process

Text Book(s):

- *Materials Science and Engineering* by William D. Callister, John Wiley & Sons, Inc.
- *Elements of Materials Science and Engineering* by Lawrence H. van Vlack.

Reference Book(s):

- *Elements of Ceramics: F.H Norton*
- *Fundamentals of Ceramics: Barsoum*
- *Introduction to Ceramics: W.D. Kingery*
- *Physical Ceramics for Engineers: Van Vlack*
- *Handbook of Ceramics: Editor S. Kumar Ceramic*
- *Materials for Electronics: R.C. Buchanon*

Course Code	Subjects (Theory/ Practical)	Contact Hours			Credits
		L	T	P	
MS502	Materials Characterization Techniques	3	1	0	4
Course Objectives: • To introduce various materials characterization techniques, their basic principles, and capabilities • To enable the student to understand the structure-property relationship of a material through materials characterization • To enable the student to learn and understand the working principle of a few sophisticated instruments through practical demonstration					

Unit I: Microscopy and Imaging- Fundamentals of Imaging: magnification, resolution, depth of field and depth of focus, aberration and astigmatism, SEM: imaging modes, image contrast, illustrative applications, Basic principle and components of TEM: Contrast mechanisms, bright field, dark field, TEM application in crystal defect analysis, Electron diffraction in TEM

Unit II: Diffraction Techniques- Concepts of diffraction, scattering, and radiation-matter interactions, X-ray diffraction, structure factor determination, phase identification, strain, and crystallite size determination.

Unit III: Spectroscopic Techniques- Basis of Spectroscopic analysis, EDS, and WDS applications, X-ray Photoelectron Spectroscopy and Auger electron spectroscopy

Unit IV: UV-visible spectroscopy - Beer's law, Instrumentation, Quantitative analysis; Vibrational spectroscopy- Raman and Infrared, Principles of vibrational spectroscopy, Infrared and Raman activity, Fourier transform infrared spectroscopy, Instrumentation, Applications

Unit V: Thermo gravimetric analysis (TGA), Differential thermal analysis (DTA), Differential scanning calorimetry (DSC), Dynamic mechanical analysis (DMA): Basic theory, Instrumentation, and applications.

Course Outcomes

CO1: Working principle and capabilities of various characterization techniques

CO2: Basics of microscopic and X-ray techniques for materials characterization

CO3: Characterization of materials to evaluate structure and properties

CO4: Demonstration of microscopic techniques through Lab practicals

CO5: Summarizing spectroscopy techniques and their applications

Text Book(s):

- *Elements of X-ray Diffraction, B. D. Cullity, Prentice Hall, 2001*
- *Solid State Chemistry and its Applications, Anthony R. West, Wiley.*

Reference Book(s):

- *Materials Characterization, ASM Handbook Vol 10.*
- *Characterization of Materials, Vol 1, Elton N. Kaufmann*

Course Code	Subjects (Theory)	Contact Hours			Credits
		L	T	P	
MS503	Thermodynamics, Kinetics, and Phase Transformations	3	0	0	3
Course Objectives: • To introduce the basic principles of thermodynamic concepts • To impart the knowledge of thermodynamic relations among variables and their transformations					

- To demonstrate the statistical thermodynamics, free energy equation, and single component system - To introduce the binary system, phases formation, and chemical potential
Unit I: Simple and composite systems, phases, Internal energy, Enthalpy, Entropy, Gibbs Free energy, Specific heat, Laws of thermodynamics, Reversible and Irreversible processes. Generation of Auxiliary Functions: Legendre transforms, Coefficient relations, Maxwell relations, Thermodynamic relations among state functions variables, and its application to solids. Unit II: Free energy of the single component system: Free energy as a function of temperature, Clausius-Clapeyron Equation, Driving force for solidification. Unit III: Solution thermodynamics: Entropy of mixing, Enthalpy of mixing, Free energy of ideal, regular and real solutions, Chemical potential, Unary and binary phase diagrams and Gibbs free energy. Unit IV: Diffusion: Phenomenology, First and Second law of diffusion, Solution to diffusion equations and error function, Types of diffusion Unit V: Solidification of pure metals and alloys, nucleation and growth, diffusional solid-state phase transformations (precipitation and eutectoid), martensitic transformation
Course Outcomes CO1: Understand the basic principles of thermodynamic concepts CO2: Learn the thermodynamic relations among variables and their transformations CO3: Demonstrate basics of statistical thermodynamics CO4: Analysis of free energy equation and curves and their interpretation for a single component system CO5: Detailed understanding of the binary system, phases formation, and chemical potential
Text/References <i>M. Modell and R.C. Reid, Thermodynamics and its Applications, Prentice-Hall, Englewood Cliffs, New Jersey, 1983.</i> <i>H.B. Callen, Thermodynamics and an Introduction to Thermostatistics, John Wiley & Sons, New York, 1985.</i> <i>R.T. DeHoff, Thermodynamics in Materials Science, McGraw-Hill, Singapore, 1993</i> <i>Richard E. Dickerson, Molecular Thermodynamics, W. A. Benjamin, 1969</i>

Course Code	Subjects (Theory)	Contact Hours			Credits
		L	T	P	
MS504	Polymer Synthesis, Manufacturing, and Technology	3	0	0	3
Course Objectives: To introduce classifications, properties, and characteristics of various polymers and elastomers					

• To introduce the chemistry of rubber and their applications • To impart knowledge on the preparation, properties, and applications of high-performance and specialty polymers • To enable the student to understand the types and role of additives and fillers
Unit I: Commodity and general-purpose thermoplastics: Polyethylene, Polypropylene, Polystyrene, Poly vinyl chloride, Polyesters, Acrylic Engineering Plastics: Nylon, Polycarbonate, polysulphones, ABS, Fluoropolymers Thermosetting polymers: Polyurethane, Phenol formlaydehyde, melamine formalydehyde, Epoxy, Unsaturated polyester Unit II: Natural and synthetic rubbers: Recovery of NR hydrocarbon from latex; Styrene butadience rubber, Nitrile, chloroprene rubber, butyl rubber, Silicone, thermoplastic elastomers Unit III: Biopolymers such as cellulosics, poly lactic acid, polyhydroxy butyrate Unit I V: Polymer compounding-need and significance, different compounding ingredients for rubber and plastics (Antioxidants, Light stabilizers, UV stabilizers, Lubricants, Processing aids, Impact modifiers, Flame retardants, antistatic agents. PVC stabilizers and Plasticizers) and their function, use of carbon black, polymer mixing equipment, cross-linking and vulcanization
Course Outcomes CO1: Understanding classifications, properties, and characteristics of polymers and elastomers CO2: Understanding rubber chemistry and uses CO3: Conception of various high-performance and specialty polymers CO4: Cognizance of various additives and fillers CO5: Understanding rubber vulcanization
Text Book(s) • <i>Plastics Materials, 7th Edition, J. A. Brydson, Elsevier</i>
<u>Reference Books:</u> • <i>Textbook of Polymer Science, Fred W. Billmeyer (Wiley)</i> • <i>Polymer alloys and blends by L A Utracki</i>

- *Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)*

Course Code	Subjects (Practical)	Contact Hours			Credits
		L	T	P	
MS505	Materials Laboratory	0	0	4	2

Course Objectives:

- To provide hands on training on various materials characterization techniques
- To introduce hands on training on different processes of thin film synthesis
- To provide hands on the various processing of polymers

Unit I: Metals polishing and Microstructure analysis, X-ray diffraction characterization and crystal structure determination, Sample preparation and imaging using scanning electron microscopy and interpretation

Unit II: Material synthesis by the solid-state method, Nanomaterial synthesis by hydrothermal method, Nano synthesis co-precipitation process, Material synthesis by the sol-gel technique

Unit III: Compounding of polymers, Extrusion of polymers and composites, Nanofiber manufacturing by electrospinning

Course Outcomes

CO1: Understand Metal polishing and characterization using Optical microscope, Scanning electron microscope and x-ray diffraction

CO2: Understand the different synthesis route

CO3: Understand the processing of polymers, composite and nanofiber

Text Book(s)

- *Elements of X-ray Diffraction, B. D. Cullity, Prentice Hall, 2001*
- *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.*
- *Manufacturing Processes and Materials for Engineers, L. E. Doyle, 1975.*
Powder436

- *Polymer nanocomposites: processing, characterization, and applications by Joseph H. Koo (McGraw-Hill Nanoscience and Technology)*

Reference Book(s)

- *Materials Characterization, ASM Handbook Vol 10.*
- *Characterization of Materials, Vol 1, Elton N. Kaufmann*
- *Materials Science and Engineering by William D. Callister, John Wiley & Sons, Inc.*
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Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS506	Processing of Metals and Ceramics	3	0	0	3
Course Objectives: • To introduce the working principles of various processing techniques for metals and ceramics • To impart the processing-structure relationship of various metals and ceramics • To demonstrate specialized techniques such as thin film deposition, sol-gel techniques, co-precipitation, etc.					
Unit I: Metallic processing: Casting and forming processes, rolling, forging, extrusion, Heat treatment of Ferrous and Aluminium alloys, Mechanical properties of metals					
Unit II: Processing of ceramics- Preparation of ceramic powder, Compaction, moulding, sintering, refractory manufacturing processes, Mechanical properties of ceramics					
Unit III: Thin film deposition: evaporation and sputtering techniques, chemical vapour deposition, thin film growth phenomena					
Unit IV: Practical: Metal processing- rolling and annealing, sol-gel, co-precipitation					
Course Outcomes CO1: Analyse the processing of ceramics CO2: Comprehend the processing of metals CO3: Identify the metal-forming processes CO4: Demonstration of various processing units					

Text Book(s):

- *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.*
- *Manufacturing Processes and Materials for Engineers, L. E. Doyle, 1975. Powder436*

Reference Book(s)

- *Metallurgy, Applications, Advantages and Limitations, Klar, Erhard, ASM, 1983, Ohio.*
- *Extrusion: the definitive processing guide and handbook, Giles, Harold F.; Wagner, JohnR.; Mount, Eldridge M, 2005.*

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS507	Polymer Processing and Rheology	3	1	0	4

Course Objectives:

- To introduce the working principles and capabilities of various polymer processing techniques
- To introduce the concepts of Newtonian and non-Newtonian fluids and constitutive equations
- To familiarize the student with viscoelasticity, rheological measurements, and various models

Unit I: Polymer Processing Compression molding, transfer molding, injection molding, blow molding, reaction injection molding, filament winding, SMC, BMC, DMC, extrusion, pultrusion, calendaring, rotational molding, thermoforming, powder coating,

Unit II: Rubber processing in two-roll mill, internal mixer.

Unit III: Flow of Newtonian and non-Newtonian fluids, different flow equations, dependence of shear modulus on temperature, molecular/segmental deformations at different zones and transitions.

Unit IV: Measurements of rheological parameters by capillary rotating, parallel plate, cone-plate rheometer. Visco-elasticity- creep and stress relaxations, mechanical models, control of rheological characteristics through compounding, rubber curing in parallel plate viscometer, ODR and MDR.

Course Outcomes

CO1: Learn the working and principles of polymer processing methods

CO2: Understand the rubber processing and rheology

CO3: Knowledge of Newtonian and non-Newtonian rheology

CO4: Learn the concepts of viscoelasticity and mechanical behavior of polymers

Text Book(s)

- *Principles of Polymer Processing, 2006, 2nd Edition, Wiley Publisher, Zehev Tadmor, Costas G. Gogos*
- *Rheology Applied in Polymer Processing 1st Edition, 2022, CRC Press by Gupta, B. R.*

Reference Books:

- *Understanding rheology, Oxford University Press, 2001, Faith A. Morrison*
- *Polymer Rheology: Fundamentals and Applications, 2014, Hanser Publisher, Tim A. Osswald and Natalie Rudolph*

Course Code	Subjects (Theory)	Contact Hours			Credits
		L	T	P	
MS508	Functional Materials	3	1	0	4
Course Objectives: • To introduce the fundamentals of functional materials such as the shape memory effect and superelasticity • To impart the concepts of magnetic materials and their applications • To explain the optoelectronic and optical properties of semiconducting materials • To introduce the concepts of metal oxide-based sensors					
Unit I: Shape memory and Superelastic alloys: shape memory effect, thermodynamics of martensitic transformation, Stress-induced martensite and superelasticity, Ni-Ti and Ni-Al based alloys and their applications.					
Unit II: Magnetic materials: Soft and hard magnetic materials, remnant magnetic material, rare earth magnets, Finemet alloys.					
Unit III: Opto-electronic Materials: Optical properties of semiconductors, absorption and emission processes, Electronic materials such as GaAs and GaN.					
Unit IV: Sensor: Metal oxide-based sensors, Principles of operation					
Course Outcomes CO1: Understand the basics of shape-memory alloys and martensitic transformation CO2: Learn the concepts of magnetic properties of materials CO3: Learn the optoelectronic and optical properties of materials CO4: Knowledge of metal-oxide-based sensing materials and their applications					

Text/References

Shape memory Materials: K. Otsuka and C. M. Wayman; Cambridge University Press
Principles of Electronic Materials and Devices: S. O. Kasap; McGraw Hill Publications

Course Name: Principles of Metallurgy**Course Code: MS509**

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS509	Principles of Metallurgy	3	0	0	3

Course Outcomes (CO):

CO-1:	To understand diffusion in metals and alloys
CO-2:	To learn liquid and solid-state transformation in metals
CO-3:	To know phases and microstructure of steel and light alloys
CO-4:	To learn various heat treatments of steel and light alloys, and deformation and strengthening concepts.

	Syllabus Details
Unit I	Diffusion in ideal, nonideal, substitutional and interstitial solid solutions, Fick's First law, Fick's second law, Self diffusion in pure metals, diffusion along grain boundaries and free surfaces
Unit II	Solidification of metals, crystal growth from the liquid phase, dendritic growth, segregation, solid state transformation, homogeneous nucleation and heterogeneous nucleation
Unit III	Phase rule, Phase diagram, Isomorphous alloy systems, The lever rule, Equilibrium heating and cooling of an isomorphous alloy, Microstructure, Eutectic, Fe-FeC diagram
Unit IV	TTT and CCT diagrams for carbon steel, Heat treatment of steels, and Aluminum alloys. Deformation and strengthening mechanisms

Textbooks

- *Physical Metallurgy Principles, Robert E Reed-Hill, EWP Pvt, Ltd, 2019*

Reference Book(s):

- *Mechanical Metallurgy, G.E. Dieter, McGraw-Hill book company, 1988*
- *Mechanical behaviour of Materials, Williams F Hosford, Cambridge University press, 2005*
- *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.*

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS510	Non-destructive Testing	3	0	0	3
Course Objectives: - To familiarize the concepts of various non-destructive techniques (NDT) - To enable the student to understand the importance of NDT techniques in detecting cracks and defects - To introduce a few real-time applications of these techniques through case studies					
Unit I: Visual Inspection, Liquid Penetrant Testing, Magnetic Particle Testing, Unit II: Eddy Current Testing, Ultrasonic Testing, Unit III: Acoustic Emission Technique, Radiography Technique, Unit IV: Residual Stress Analysis, In-situ Metallography, Automation and Robot in NDT, Unit V: Case study: Grain Size, Weldment, and other Structural Components.					
Course Outcomes CO1: Understanding of handy NDT (Non-destructive techniques) CO2: Knowledge of Eddy current and ultrasonic testing CO3: Concept of acoustic emission and radiography techniques CO4: Understanding automated NDT techniques CO5: Case studies on NDT techniques application					
Test Book(s)					
<i>Non-destructive Testing of welds, Baldev Raj, C.V. Subramanian and T. Jayakumar, Narosa Publishing House, 2000, Delhi.</i>					
Reference book(s) <i>International Advances in non-destructive testing, (Ed.) W. J. McGonnagle, Gordon and Breach Science Publishers, 1981, NY.</i> <i>Non-destructive Testing, Views, Reviews, Previews, (Ed.) L.L.Alston, Oxford University Press, 1970</i> <i>Nondestructive Evaluation and quality control, ASM handbook, Volume 17,ASM International</i>					

Course Name: Polymer Characterization and Testing
Course Code: MS511
Course Objectives: • To impart knowledge on various physical characterizations of polymers • To introduce various mechanical properties of polymers • To familiarize the thermal and thermo-mechanical properties of polymers • To introduce the optical and electrical properties of polymers
Unit I: Concept of molecular weight distribution and its significance, concept of average molecular weight, determination of number average, weight average, viscosity average and Z-average molecular weights, polymer crystallinity, analysis of polymers using IR, XRD, thermal (DSC, DMTA, TGA), microscopic (optical and electronic) techniques, Molecular wt. distribution: Broad and Narrow, GPC, Mooney viscosity. Polymer solubility and swelling Unit II: Mechanical-static and dynamic, tensile, flexural, compressive, abrasion, endurance, fatigue, hardness, tear, resilience, impact, toughness. Unit III: Conductivity-thermal and electrical, dielectric constant, dissipation factor, power factor, electric resistance, surface resistivity, volume resistivity, Unit IV: Swelling, aging resistance, environmental stress cracking resistance, limiting oxygen index. Heat deflection temperature –Vicat softening temperature, Brittleness temperature, Glass transition temperature, Coefficient of thermal expansion, Shrinkage, Flammability, dielectric constant, dissipation factor, power factor. Unit V: Optical Properties - Refractive Index, Luminous Transmittance and Haze, Melt flow index
Course Outcomes CO1: Understand the molecular weight concepts and physical properties of polymers CO2: Learn the techniques for characterizing various polymer CO3: Understand the mechanical behavior of polymers CO4: Knowledge of thermal and thermo-mechanical properties of polymers CO5: Understand the electrical and optical properties of polymers
Reference Books: • <i>Textbook of Polymer Science, Fred W. Billmeyer (Wiley)</i> • <i>Polymer alloys and blends by L. A. Utracki</i> • <i>Polymer nanocomposites: processing, characterization, and applications by Joseph</i>

H. Koo (McGraw-Hill Nanoscience and Technology)

Course Name: Corrosion and mitigation

Course Code: MS512

Course Outcomes (CO):

CO-1:	Introduction to various forms of corrosion, concept of free energy, partial pressure and related thermodynamics, corrosion mitigation
CO-2:	To learn various form of high temperature corrosion
CO-3:	Analysis of corrosion data and identify corrosion rate
CO-4:	Understand corrosion in various room temperature applications
CO-5:	Understand different applications of high temperature corrosion

	Syllabus Details
Unit I	Introduction to corrosion, Different forms of corrosion, Electrochemical principles of Corrosion, Localized & Metallurgical influenced Pitting, Crevice, Galvanic & Intergranular Corrosion
Unit II	Electro chemical impedance, Tafel, Open circuit potential, determination of corrosion rate, defect interactions, scale growth kinetics and mechanisms, Wagner's parabolic scale growth process, other types of kinetics laws and mechanisms, morphological aspects in the growth of thick scales.
Unit III	Aspects of thermodynamics, Ellingham diagram various forms of high temperature corrosion including molten salt corrosion, kinetics, transport properties, scale morphologies.
Unit IV	Protective Coatings Introduction, coatings & Coating Processes, Supplementary protection systems, Surface preparation. Classification of inhibitors, Corrosion inhibition Mechanism, Selection of an inhibitor system, Cathodic and Anodic Protection principles & classifications.
Unit V	Case studies – Corrosion in seawater, Corrosion in steam and gas turbine, Gasifiers and Boilers

Textbooks

- *Per Kofstad, High Temperature Corrosion, Elsevier Applied Science, 1988.*
- *Mars G. Fontana, Corrosion Engineering, 3rd Ed., McGraw-Hill, Singapore, 1987*

Reference Book(s):

- *N. Birks and G.H. Meier, Introduction to Oxidation of Metals, Edward Arnold, London, 1983.*

- *A.S. Khanna, Introduction to High Temperature Oxidation and Corrosion, ASM International, Materials Park, Ohio, 2002.*
- *Phase transformation in metals and alloys, Porter and Easterling.*

Course Name: Nanoscience and Nanotechnology

Course Code: MS513

Course Objectives:

- To introduce the concepts of nanotechnology and its evolution
- To impart knowledge of various nanomaterial and their structure and synthesis
- To introduce the properties and characteristics of nano-sized materials
- To familiarize the applications and prospects of nanotechnology

Unit I: Overview of Nanostructures and Nanomaterials; Synthesis of Nanomaterials: Types and strategies for synthesis of nanomaterials;

Unit II: Crystalline nanomaterials and defects therein; Hybrid nanomaterials; Multiscale hierarchical structures built out of nanosized building blocks (nano to macro); Nanomaterials in Nature: Nacre, Gecko, Teeth; Nanostructures: Carbon Nanotubes, Fullerenes, Nanowires, Quantum Dots.

Unit III: Cells response to Nanostructures; Surfaces and interfaces in nanostructures, Ceramic interfaces, Superhydrophobic surfaces, Grain boundaries in Nanocrystalline materials,

Unit IV: Thermodynamics of Nanomaterials; Overview of properties of nanostructures and nanomaterials; Overview of characterization of nanostructures and nanomaterials

Unit V: Applications of Nanotechnology in various fields

Course Outcomes

CO1: Knowledge of the basics of nanotechnology

CO2: Understanding the behavior of materials in the nano-scale

CO3: Learn the synthesis and properties of nanomaterials

CO4: Knowledge of the application of nanotechnology

Text Book(s)

- *T. Pradeep, NANO: The Essentials, Tata McGraw-Hill Publisher, 2007. ISBN-13:978-0-07-061788-9.*

Reference Book(s)

• K. Haghi, G. E. Zaikov, *Advanced Nanotube and Nanofiber Materials*, Nova Science Publishers Inc, 2012

• Vladimir V. Mitin, Viatcheslav A. Kochelap, Michael A. Stroscio, *Introduction to Nanoelectronics: Science, Nanotechnology, Engineering, and Applications*, Cambridge University Press, 2008

Course Name: Chemistry of Polymers**Course Code: MS514****Course Objectives:**

- To introduce various polymerization methods and their kinetics
- To familiarize the student with the polymerization techniques
- To impart the knowledge of block- and graft-co-polymers
- To introduce the structure-property relationship in polymers

Unit I: Chemistry of High Polymers Monomers, functionality, degree of polymerizations, classification of polymers, glass transition, melting transition, criteria for rubberiness.

Unit II: Polymerization methods: addition and condensation; their kinetics, metallocene polymers and other newer methods of polymerization, copolymerization, monomer reactivity ratios, and its significance, kinetics, different copolymers, random, alternating, azeotropic copolymerization.

Unit III: Block and graft copolymers, techniques for polymerization: bulk, solution, suspension, emulsion.

Unit IV: Concept of intermolecular order (morphology) – amorphous, crystalline, orientation states. Factor affecting crystallinity. Crystalline transition. Effect of morphology on polymer properties.

Course Outcomes

CO1: Understand the basics of polymerization reactions and their kinetics

CO2: Knowledge of polymerization techniques and their applications

CO3: Learn the concepts of block- and graft-co-polymers

CO4: Understand the fundamentals of structure-property relationship

Reference Books:

- *Textbook of Polymer Science*, Fred W. Billmeyer (Wiley)
- *Polymer alloys and blends* by L A Utracki
- *Polymer nanocomposites: processing, characterization, and applications* by Joseph H. Koo (McGraw-Hill Nanoscience and Technology)

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS515	Additive Manufacturing of Materials	3	0	0	3
Course Objectives: • To introduce the concepts of additive manufacturing techniques • To familiarize with the liquid and solid-state additive manufacturing • To impart knowledge of various types of additive manufacturing and their capabilities and limitations • To introduce case studies related to polymer, ceramics, and metal additive manufacturing					
Unit I: Basic Introduction Overview- History- Need classification- Additive Manufacturing Technology in product development- Materials for Additive Manufacturing Technology- Tooling- Applications					
Unit II: Solid and liquid-based additive manufacturing Classification – Liquid-based system- Stereolithography Apparatus (SLA)- Principle, process, advantages, and applications – Solid-based system- Fused Deposition Modeling- Principle, process, advantages and applications, Laminated object Manufacturing.					
Unit III: Powder-based additive manufacturing Selective Laser Sintering- Principles of SLS process- Process, advantages and applications, Three-Dimensional Printing – Principle, Process, advantages and applications- Laser Engineered Net Shaping (LENS), Electron Beam Melting.					
Unit IV: CASE STUDIES Case studies for metals and alloys, Ceramics and Polymers					
Course Outcomes CO1: Knowledge of basics and application of additive manufacturing CO2: Understanding liquid and solid-state additive manufacturing					

CO3: Concepts of various types of additive manufacturing and challenges

CO4: Case studies on metal, ceramic and polymer additive manufacturing

Test Books:

- Chua C.K., Leong K.F., and Lim C.C., *“Rapid prototyping: Principles and applications”*. Third Edition, World Scientific Publishers, 2010.
- Gebhardt A., *“Rapid prototyping”*, Hanser Gardener Publications, 2003.

Reference Books:

- Liou L.W. and Liou F.W., *“Rapid Prototyping and Engineering applications: A tool box prototype development”*, CRC Press, 2007.
- Kamrani A.K. and Nase E.A., *“Rapid Prototyping: Theory and practice: Springer*, 2006.
- Hilton P.D. and Jacobs P.F., *“Rapid Tooling: Technologies and Industrial Applications”*, CRC press, 2000.
- Douglas Bryden, *“CAD and Prototyping for Product Design”*, 2014

Course Name: Biomaterials

Course Code: MS516

Course Objectives:

- To introduce the basics of biomaterials and the related concepts
- To familiarize the student with different classes of biomaterials
- To introduce the concepts of nano-biomaterials and their properties
- To impart knowledge on various processes used for manufacturing biomaterials

Unit I: Introduction to biomaterials, Tissue Engineering, Biocompatibility, Biodegradation Biofluids and medical devices, Biostructures

Unit II: Ceramic-based biomaterials, metallic biomaterials, polymer-based biomaterials, Biofluidic, medical devices, Biostructures

Unit III: Nano-biomaterials: Self-assembly of nanomaterials, hydrophilic, hydrophobic and surfaces, biomimicking

Unit IV: Medical imaging, electrospinning of scaffold structures, Additive manufacturing of medical devices, biofluidics and biostructure

Unit V: Case studies: Lotus leaf, Gecko feet, Nacre/Bone. Application of nanocomposite

biomaterials: artificial biomaterials, antidrug coatings, self-cleaning surfaces, sensors, Riboswitches

Course Outcomes

CO1: Knowledge of biomaterials, biocompatibility, and tissue engineering

CO2: Learn the different classes of biomaterials and their properties

CO3: Understand the nano-biomaterials and their properties

CO4: Knowledge of biomaterials manufacturing processes

Text Book(s):

- *Biomaterials- An Introduction, Joon Park- Publisher Springer* 423

Reference Book(s):

- *Biomaterials- Principals and Applications- Joon Park- CRC Press*
- *Handbook of Biomaterial Properties- Garth Hastings- Springer*
- *Handbook of Biomaterials Properties- William Murphy- Springer*
- *Handbook of Biomaterial Properties- Jonathan Black- Chapman and Hal*

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS517	Computational Mathematics	3	0	0	3

Course Objectives:

- To lay the foundation of linear algebra that is necessary for scientific computing
- To extend the knowledge to multivariable calculus
- To familiarize the students with vector calculus
- To demonstrate the fundamentals of numerical methods applied to engineering problems

Unit I: Linear Algebra:

Algebra of real matrices: Determinant, inverse, and rank of a matrix; System of linear equations (conditions for unique solution, no solution and infinite number of solutions); Eigenvalues and eigenvectors of matrices; Properties of eigenvalues and eigenvectors of symmetric matrices, diagonalization of matrices; Cayley-Hamilton Theorem.

Unit II: Calculus of single and multiple variables:

Limit, Continuity and differentiability; Maxima and minima; Partial derivatives; Total derivative.

Unit III: Vector Calculus:

Gradient, divergence and curl; Line integrals, and Green's theorem.

Unit IV: Numerical Solution of Differential Equations:

Concepts of discretization in space/time, implicit, explicit; Taylor's series; Solution to ODEs; Classification of second order linear partial differential equations; Method of separation of variables: One-dimensional heat equation and two-dimensional Laplace equation.

Course Outcomes

CO1: Understand the basics of Linear Algebra

CO2: Recognize the principles of advanced calculus

CO3: Introduce vector calculus

CO4: Utilise numerical methods to solve differential equations

Text Book(s)

- *Advanced engineering mathematics: Kreyszig; Wiley.*
- *Advanced engineering mathematics: Jain/Iyenger; Narosa*

Reference Book(s)

- *Advanced engineering mathematics: Peter V. O'Neil Cengage Learning*
- *Advanced engineering mathematics: Alan Jeffery; Academic Press*
- *Calculus and analytic geometry: Thomas/Finney; Narosa*
- *Numerical methods for Engineers: Steven C. Chapra and Paymond P. Canale*

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS518	Computational Materials Science	3	0	0	4
Course Objectives: - To revisit and build up on the programming skills - To familiarise students with modeling and simulation by simple models - To demonstrate the multi-scale models employed in materials engineering - To introduce data-driven modeling					
Unit I: Review of programming in high-level and low-level languages Unit II: Lotka-Volterra Model: Analytical and Numerical Solution; Solving Fick's laws of Diffusion numerically in 1D using low-level language; Diffusion in 3D using advanced solvers; Random Walker model Unit III: Monte Carlo method; Ising Model; Sharp and Diffuse interface models; Phase field method for the evolution of microstructure: Cahn-Hilliard and Allen-Cahn model. Unit IV: Introduction to Machine Learning: Supervised and Unsupervised models, Fitting and visualization of multidimensional data; Data analytics using principal component analysis					
Course Outcomes CO1: Understand the basics of programming CO2: Implement the analytical and numerical solution to partial differential equations utilized in materials science CO3: Analyze the mesoscopic modelling techniques CO4: Understand the principles of data-driven modeling					
Text Book(s): <i>Introduction to Computational Science: Modeling and Simulation for the Sciences</i>, Princeton University Press, A. B. Shiflet and G. W. Shiflet <i>Introduction to Computational Materials Science</i> – Richard LeSar, Cambridge University Press					
Reference Book(s): <i>Computational Materials Engineering: An Introduction to Microstructure Evolution</i>, Elsevier Academic press, K. G. F. Janssens, D. Raabe, E. Kozeschnik, M. A. Miodownik, B. Nestler <i>David V. Hutton, Fundamentals of Finite Element Analysis</i> <i>Mathematic physics (V. Balakrishnan)</i> <i>Numerical Recipes in C(William H. Press, Vetterling, Teutolsky, Flannery)</i>					

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS519	Composite Materials and Polymer Blends	3	0	0	3
Course Objectives: - To introduce the concepts of composite materials and their types, matrices, and reinforcements - To impart the knowledge of various filler-reinforced polymer composites, their processing techniques, and the mechanics of composites - To introduce preparation and properties of metal-matrix and ceramic-matrix composites - To introduce the concepts of polymer blends and their thermodynamics of miscibility					
Unit I: Matrix, reinforcement, types of reinforcing fillers, continuous and discontinuous fibers, carbon, glass, aramid, and other fibers, preparation methods and properties, particulate fillers, dispersion and interfacial phenomena, nanofillers, functional fillers. Unit II: Polymer Matrix Composites: Polymer resins – thermosetting resins, thermoplastic resins – reinforcement fibers – rovings -woven fabrics – nonwoven random mats – various types of fibers. PMC processes – hand layup processes – spray up processes – compression molding – reinforced reaction injection molding – resin transfer molding – Pultrusion – Filament winding – Injection molding. Fiber-reinforced plastics (FRP), Glass Fibre Reinforced Plastics (GFRP). Mechanics of Composites, basic constitutive equations, rule of mixture, Halpin-Tsai equations etc. Applications of PMC in aerospace, automotive industries Unit III: Metal Matrix Composites: Characteristics of MMC, various types of metal matrix composites alloy vs. MMC, advantages of MMC, limitations of MMC, Reinforcements – particles – fibers. Effect of reinforcement – volume fraction – rule of mixtures. Processing of MMC – powder metallurgy process – diffusion bonding -stir casting – squeeze casting, a spray process, Liquid infiltration In-situ reactions-Interface-measurement of interface properties- applications of MMC in aerospace, automotive industries Unit IV: Ceramic matrix composites, carbon-carbon composites, processing, manufacturing, properties, and applications in aerospace and automotive components Unit V: Introduction to polymer blends, nanostructured materials and nanocomposites, Thermodynamics of polymer blends, mixing, factors governing miscibility, immiscible polymers, and phase separation. Influence of interface on the property of blends and nanocomposites. Compatibilizers and compatibilization. Blends of amorphous & semi-					

crystalline polymers, inter-penetrating networks, thermoplastic and thermoset blends, rubber-toughened polymers, and particulate and fiber-reinforced composites.

Course Outcomes

CO1: Understanding of various reinforcements and matrices

CO2: Knowledge of the role of interface in mechanical properties

CO3: Understanding fiber-reinforced composites and challenges

CO4: Knowledge of composite processing methods

CO5: Understanding of polymer nanocomposites and blends

Text Books:

- *Mathews F. L. and Rawlings R. D., Composite Materials: Engineering and Science, 1st Edition, Chapman and Hall, London, England, 1994.*
- *Chawla K. K., Composite Materials, Second Edition, Springer – Verlag, 1998.*
- *Introduction to Materials Engineering, William Callister*
- *Polymer alloys and blends by L A Utracki*

Reference Books:

- *Clyne, T. W. and Withers, P. J., Introduction to Metal Matrix Composites, Cambridge University Press, 1993.*
- *Strong, A.B., Fundamentals of Composite Manufacturing, SME, 1989.*
- *Sharma, S.C., Composite Materials, Narosa Publications, 2000.*
- *Broutman, L.J. and Krock, R.M., Modern Composite Materials, Addison-Wesley, 1967.*
- *ASM Hand Book, Composites, Vol.21, ASM International, 2001.*

*M. Sc. in Applied
Chemistry*

DEPARTMENT OF APPLIED CHEMISTRY, ENERGY and ENVIRONMENT

M.Sc. in Applied Chemistry

ABOUT THE DEPARTMENT:

The Department of Applied Chemistry started in 1976 with the aim to impart education and training to DRDO work force in the area of high energy materials and propellants. Over the years Department has moved on to cater to the need of DRDO and civilian students in order to bring the DRDO achievements closer to our society. The Department's aim is to contribute to our understanding of the chemical world through excellence in observational, theoretical and experimental science and to extend quantitative and other appropriate methodologies to address problems in the fields of applied chemical science. In Applied Chemistry, we are endowed with faculties who are dedicated teachers and distinguished researchers that carry out cutting-edge research in all modern areas of Applied Chemistry, as well as in inter-disciplinary areas like nanoscience and technology, high energy materials, polymer science and technology etc.

The first PhD of DIAT (DU) was from the Department of Applied Chemistry and currently it is amongst the Departments guiding very high number of PhD scholars and research publications in DIAT. In addition to PhD, there are numbers of M. Tech. students carrying their PG education. We provide a vibrant and creative learning environment for our students and researchers. We also participate extensively in R&D for various DRDO labs and industries.

In recent times, the Department has made significant contributions towards revenue generation through grant-in-projects and customized courses.

Description about the programmes:

M.Sc. in Applied Chemistry programme is designed to impart latest knowledge in the field of chemistry to defence personnel and civilian students. The course contents are related to concepts of chemistry, practical applications and skill development.

Eligibility:

Bachelors of Science (B.Sc.) in Chemistry, Physics, Mathematics or Biology.

DEFENCE INSTITUTE OF ADVANCED TECHNOLOGY (DU)

DEPARTMENT OF APPLIED CHEMISTRY

M.Sc. in Applied Chemistry

(Syllabus Effective from Acad. Year July 2025 as per NEP)

Batch 2025-2027

SEMESTER I			
No	Course Code	Courses	Credit
1	AC 501	Inorganic Chemistry-I	4
2	AC 502	Organic Chemistry-I	4
3	AC 503	Physical Chemistry-I	3
4	AC 504	Analytical Chemistry	3
5	AC 512	App Chemistry Laboratory-I	2
6	RM 501	Research Methodology	4
		Total Credit of I Semester	20
SEMESTER II			
No	Course Code	Courses	Credit
1	AC 521	Inorganic Chemistry-II	4
2	AC 522	Organic Chemistry –II	3
3	PE-I	ELECTIVE -I	3
4	PE-II	ELECTIVE -II	3
5	PE-III	ELECTIVE -III	3
6		On Job Training/Internship/Field Project (120 Hrs.)	4
		Total Credit of II Semester	20
LIST OF ELECTIVE COURSES FOR SEMESTER- II (Students are requested to selected any THREE courses from the following list of electives as PE –I, PE-II and PE-III with equal credit ONLY)			
1	AC 523	Molecular Spectroscopy-I	3
2	AC 524	Polymer Chemistry	3
3	AC 525	Recent Advances in Chemistry	3
4	AC 526	Forensic Chemistry and Toxicology	3
5		Elective from Applied Chemistry Dept with equal credit	3
6		Elective from any Department with equal credit only	

7		Online courses from NPTEL, MOOC. SWAYAM (equal credit)	3

SEMESTER III			
No	Course Code	Courses	Credit
1	AC 531	Physical Chemistry-II	4
2	AC 532	Industrial Chemistry	3
3	PE-IV	ELECTIVE IV	3
4	PE-V	ELECTIVE V	3
5	PE-VI	ELECTIVE VI	3
6	RP 541	PROJECT - I	6
Total Credit of III Semester			22

LIST OF ELECTIVE COURSES FOR SEMESTER- III

(Students are requested to select any **THREE** courses from the following list of electives as PE –I, PE-II and PE-III with **equal credit ONLY**)

1	AC-533	Organo-metallic Chemistry and Catalysis	3
2	AC-534	Molecular Spectroscopy -II	3
3	AC-535	Defence Chemistry	3
4	AC 536	Paints, Pigments and Varnishes	3
5	AC- 537	Drug Design and Pharmacology	3
6		Elective from Applied Chemistry Dept with equal credit	3
7		Elective from any Department with equal credit only	3
8		Online courses from NPTEL, MOOC. SWAYAM (equal credit)	3

SEMESTER IV			
1	RP 542	PROJECT - II	18
Total Credit of IV Semester			18

- On Job Training (OJT) evaluation to be conducted at the end of first year.
- Maximum of 6 credits to be awarded for Professional Electives (Approved by BoS for ONLINE courses NEPTL during II and III Semester).

DETAILED SYLLABUS OF SEMESTER –I

Course Code	Course Name	Credits
<u>AC 501</u>	<u>INORGANIC CHEMISTRY-I</u>	4
Course Objectives: ➤ To develop an insight into the basic knowledge of inorganic chemistry ➤ To understand chemical bonding, coordination compounds, f-block elements and their theories ➤ To apply the knowledge and understanding in the areas of chemical bonding, coordination compounds and f-block elements for solving existing challenges faced in various chemical and industrial area		
<u>UNIT I: MAIN GROUP ELEMENTS</u> Hydrides, halides, oxides, oxoacids, nitrides, chalcogenides – shapes and reactivity. Structure and bonding of boranes, carboranes, silicones, silicates, boron nitride, borazines and phosphazenes. Allotropes of carbon, phosphorous and sulphur. Industrial synthesis of compounds of main group elements. Chemistry of noble gases, pseudo-halogens, and interhalogen compounds. Acid-base concepts and principles <u>UNIT II: TRANSITION ELEMENTS</u> Coordination chemistry – structure and isomerism, theories of bonding. Energy level diagrams in various crystal fields, CFSE, applications of CFT. Electronic spectra of transition metal complexes: spectroscopic term symbols, selection rules, nephelauxetic effect and Racah parameter, charge-transfer spectra. Magnetic properties of transition metal complexes. Metal-metal multiple bonds <u>UNIT III: LANTHANIDES AND ACTINIDES</u> Recovery, Periodic properties, spectra and magnetic properties. <u>UNIT IV APPLICATION OF INORGANIC CHEMISTRY IN INDUSTRY</u> Manufacture of inorganic products on a large scale such as the heavy inorganics (chloralkalis, sulfuric acid, sulfates) and fertilizers (potassium, nitrogen, and phosphorus products)		
Course Outcomes After completing this course, the students will be able to: ➤ To understand structure and bonding of main group elements, ➤ Students can familiarize with transition metals and their applications ➤ To understand the basic properties of rare earth elements ➤ Use of inorganic chemistry knowledge for application in Industry (heavy inorganics, fertilizers) ➤ Overall students can solve the problems related to Inorganic chemistry		

Text Books
1. Concise Inorganic Chemistry - J. D. Lee. Wiley India 2. Inorganic Chemistry -Meissler & Tarr, Pearson New International 3. Mechanism of Inorganic Reactions – Fred Basolo, Ralph G. Pearson
Reference Books Inorganic Chemistry: Principles of Structure and Reactivity – James E. Huheey

Course Code	Course Name	Credits
<u>AC 502</u>	<u>ORGANIC CHEMISTRY-I</u>	4
Course Objectives ➤ To develop an insight the basic knowledge of organic chemistry ➤ To understand structure and reactivity, aromatic nucleophilic substitution, stereochemistry of compounds ➤ To apply the knowledge and understanding in the areas of structure and reactivity, aromatic nucleophilic substitution, stereochemistry of organic compounds for solving existing challenges faced in various chemical and industrial areas		
<u>UNIT I: STEREOCHEMISTRY</u> Chirality and symmetry of organic molecules with or without chiral centres and determination of their absolute configurations. Relative stereochemistry in compounds having more than one stereogenic centre. Homotopic, enantiotopic and diastereotopic atoms, groups and faces. Stereoselective and stereospecific synthesis. Conformational analysis of acyclic and cyclic compounds. Geometrical isomerism and optical isomerism. Configurational and conformational effects, atrop isomerism, and neighbouring group participation on reactivity and selectivity/specificity.		
<u>UNIT II: REACTION MECHANISMS</u> Basic mechanistic concepts – kinetic versus thermodynamic control, Hammond’s postulate and Curtin-Hammett principle. Methods of determining reaction mechanisms through kinetics, identification of products, intermediates and isotopic labelling. Linear free-energy relationship – Hammett and Taft equations. Nucleophilic and electrophilic substitution reactions (both aromatic and aliphatic). Addition reactions to carbon-carbon and carbon-heteroatom (N and O) multiple bonds. Elimination reactions. Reactive intermediates – carbocations, carbanions, carbenes, nitrenes, arynes and free radicals. Molecular rearrangements.		

UNIT III: ORGANIC SYNTHESIS

Synthesis, reactions, mechanisms and selectivity involving the following classes of compounds – alkenes, alkynes, arenes, alcohols, phenols, aldehydes, ketones, carboxylic acids, esters, nitriles, halides, nitro compounds, amines and amides. Concepts of multistep synthesis – retrosynthetic analysis, strategic disconnections, synthons and synthetic equivalents. Selectivity in organic synthesis – chemo-, regio- and stereoselectivity. Protection and deprotection of functional groups. Concepts of asymmetric synthesis – resolution (including enzymatic), de-symmetrisation and use of chiral auxiliaries, organo catalysis. Carbon carbon and carbon-heteroatom bond forming reactions through enolates (including boron enolates), enamines and silyl enol ethers. Stereoselective addition to C=O groups (Cram, Prelog and Felkin-Anh models).

Course Outcomes

After completing this course, the students will be able to:

- To understand the detailed aspects of Stereochemistry including optical and geometrical isomerism.
- To gain knowledge on methods of determination of reaction mechanism, various reaction intermediates
- Design and conceptualization of organic synthesis with several examples

Text Books

1. Stereochemistry Conformation and Mechanism -**P.S. Kalsi**
2. Stereochemistry of Organic Compounds - **E. L. Eliel**
3. A Guidebook to Mechanism in Organic Chemistry – **Peter Sykes**
4. Modern Methods of Organic Synthesis – **William Carruthers, Iain Coldham**
5. Organic Synthesis the disconnection approach – **Stuart Warren**
6. Advanced organic Chemistry: **Jerry March, Wiley & Sons**

Reference Books: Organic Chemistry -**Clayden, Greeves, Warren and Wothers**

Course Code	Course Name	Credits
<u>AC 503</u>	<u>PHYSICAL CHEMISTRY-I</u>	3
➤ To understand the concept of thermodynamics w.r.t. to entropy, free energy, temp etc. ➤ To understand chemical potential and their variation with Temperature and Pressure. Study of non-ideal systems, Gibbes Duhem equations and applications ➤ Study of thermodynamic criteria for non-equilibrium states, Basic Postulates and Methodology with different laws and relations. ➤ To understand the concept of distribution, corresponding distribution laws and applications		

- Study of ideal and non-ideal solutions w.r.t to various laws and their applications.

UNIT I: THERMODYNAMICS

Brief description of the laws of thermodynamics, Concepts of Entropy and Residual Entropy, Free energy and its Temperature dependence, Thermodynamic Equilibria and Free Energy Functions, Physical Equilibria Involving Phase Transitions, Thermodynamic Maxwell Relations, Statistical Thermodynamics

UNIT II: EQUILIBRIUM THERMODYNAMICS

Partial molar quantities, Determinations of the partial molar quantities, Chemical potential and other thermodynamic functions, Variation of chemical potential with temperature and pressure, Chemical potential for Ideal gas mixture, Thermodynamic Functions of Mixing, Concepts of Fugacity and its determination, non-ideal systems: Excess functions for non-ideal solutions.

UNIT III: NON-EQUILIBRIUM THERMODYNAMICS

Thermodynamic criteria for non-equilibrium states, Basic Postulates and Methodology, Onsager's Theory, Phenomenological Laws and Equations, Transformations of the generalized fluxes and forces, Microscopic Reversibility and Onsager's Reciprocal Relations, Entropy Production and entropy flow, Theorem of Minimum Entropy Production, Chemical Reactions, Coupled Reactions and Electro-kinetic Phenomena.

UNIT IV: CHEMICAL EQUILIBRIUM

Ideal and Non-ideal solutions, Raoult's Law and Henry's Law, Chemical equilibria. Dependence of equilibrium constant on temperature and pressure. Ionic mobility and conductivity. Debye-Hückel limiting law. Debye-Hückel-Onsager equation. Standard electrode potentials and electrochemical cells. Nernst Equation and its application, relationship between Electrode potential and thermodynamic quantities.. Phase rule. Clausius- Clapeyron equation. Phase diagram of one component systems: CO₂, H₂O, S; two component systems: liquid- vapour, liquid-liquid and solid-liquid systems. Fractional distillation. Azeotropes and eutectics.

Course Outcomes

After completing this course, the students will be able to:

- Understanding of basic chemical thermodynamics
- To familiarize equilibrium and non-equilibrium thermodynamics
- To understand and application of various laws of thermodynamics

Text Books
1. Elements of Chemical thermodynamics – Leonard Nash, Dover Publications 2. Chemical Thermodynamics–Peter A. Rock 3. A text book of Physical Chemistry (Vol-V) – K. L. Kapoor
Reference Books
Fundamentals of Molecular Spectroscopy – Colin N. Banwell

Course Code	Course Name	Credits
<u>AC 504</u>	<u>ANALYTICAL CHEMISTRY</u>	3
➤ To understand basic concept of instrumental methods of analysis, their advantages, disadvantages and applications. ➤ Study the principles and work of mass spectroscopy ➤ To understand the principles and working electroanalytical techniques ➤ Understand basic principles of differential pulse volumetry and coulometry and study applications of cyclic voltammetry in organic and inorganic chemistry. ➤ Study of florescence energy and their applications in measurement. ➤ To understand the basic principles of TGA and DSC and their inorganic applications.		
<u>Unit I: CONCEPTS OF ANALYTICAL CHEMISTRY</u> Classification of Analytical Methods: An overview of Classical methods, Types of Instrumental methods Selection of an analytical methods and their performance criteria. Concepts of optical methods: Electromagnetic spectrum, transitions, components in optical instruments, sources, description of LASER, wavelength selectors, mono chromator functioning, effective band width, detectors and description of diode array type detector. Atomic Absorption Spectrometry: Principle, interferences, use of electro thermal analyser, <u>Unit II: ELECTRO-ANALYTICAL TECHNIQUES</u> Electrochemistry, Nernst equation, Potentiometry, Amperometry, Electrochemical analysis, Standard hydrogen electrode (SHE), Calomel electrode, Ion selective electrodes (ISE), etc. and their applications. <u>Unit III: SPECTROCHEMICAL METHODS</u> Introduction, electronic spectra and molecular structure, Concepts of optical methods: Electromagnetic spectrum, transitions, components in optical instruments, General instrumentation for spectrometer, Absorbance and chromophores, Beer-Lambert's Law. <u>Unit IV: THERMAL ANALYSIS</u>		

Thermogravimetric analysis (TGA) and its applications to organic, inorganic and polymer material characterization. Differential scanning calorimetry (DSC) and its application.

Unit V: CHROMATOGRAPHY

Fundamental of chromatographic separations, retention time, retention volume, distribution ratio, K factor. TLC, High Performance Liquid Chromatography (HPLC) its application to organic compounds. Gas Chromatography (GC) and applications of chromatography.

Course Outcomes

After completing this course, the students will be able to:

- To understand the basic concepts of analytical chemistry
- To understand various types of spectroscopic techniques and their applications
- To thermal analysis
- To understand the detailed aspects of various separation methods

Text Books

1. Analytical Chemistry Skoog and Skoog,
2. Electroanalytical Methods, Fritz Scholz, Springer
3. Thermal Analysis Techniques and Applications, N.N. Kaushik and Shukla

Reference Books

Analytical Chemistry, Alka Gupta, Pragati Publication

Course Code	Course Name	Credits
AC 512	<u>APPLIED CHEMISTRY LABORATORY-I</u>	2
Course Objectives: ➤ Understand the process of synthesis and analysis of coordination complexes ➤ To develop an insight into the various experimental techniques related to distribution, heat of a reaction, adsorption, binary mixtures, phase diagrams ➤ Develop skill in synthesis of organic compound, their purification by systematic analysis ➤ Develop a skill of volumetric estimation of by titration methods		
(Any 10 Practical's of the followings) (I) Introduction to chemical laboratory safety (II) PH METRIC TITRATIONS (Any Two) 1. To determine the amount of a strong acid (like HCl) present is the given solution by titration against a strong base (like NaOH) using a pH meter. 2. To determine the amount of a weak acid (like weak) present is the given solution by titration against a strong base (like NaOH) using a pH meter 3. To determine the ISO ELECTRIC POINT of glycine by titration it with strong acid and strong base		

(III) CONDUCTOMETRIC TITRATION (Any Two)

1. Study of conductometric titration of a weak acid (CH_3COOH) against a strong base (NaOH)
2. Study of conductometric titration of a mixture of strong acid (HCl) and weak acid (CH_3COOH) against a strong base (NaOH)
3. Study of potentiometric titration of a strong acid (HCl) against a strong base (NaOH)

(IV) INORGANIC SYNTHESIS (Any Two)

1. Tris (Acetyl-acetonate) Iron (III) complex
2. Hexa-ammine nickel (II) chloride/sulphate
3. Bis(ethylene-di-ammine) copper (II) sulphate
4. Synthesis of Ni-DMG complex
5. Synthesis of Copper acetyl acetonate (II) complex

(V) INORGANIC SYNTHESIS (Any Two)

1. To prepare benzoic acid from benzaldehyde by oxidation method
2. To prepare benzylidene aniline by condensation of benzaldehyde with aniline
3. To prepare cyclohexanone oxime from cyclohexanone
4. 2,4, Di nitro phenyl hydrazone derivatives of benzaldehyde

(VI) VOLUMETRIC ESTIMATION (Any Two)

1. To determine the total hardness of given water sample
2. To determine the chemical oxygen demand of the given water sample
3. To determine the acidity of water from given water sample
4. To estimate the amount of nickel present in the given nickel sulphate solution

Course Outcomes

After completing this course, the students will be able to:

- To understand the operation of conductometry and pH metry
- To study various physico-chemical properties of mixtures
- To understand the methods of synthesis, volumetric analysis.
- To develop an insight into the various experimental techniques

Selected Text Books

1. Elias, A.J., A Collection of Interesting General Chemistry Experiments, Uni Press, (India) Pvt. Ltd., 2002.
2. Roesky, H. W.; Möckel, K., Chemical Curiosities: spectacular experiments and inspired quotes, VCH, 1996. Hand-outs prepared for the laboratory experiments: collections from various literature sources
3. I.G., Svehla, 'Vogel's Qualitative Inorganic Analysis', 6th Edn., Orient Longman New Delhi, 1987.
4. V.V., Ramanujam, 'Inorganic Semi-micro Qualitative Analysis', 3rd Edn., National Publishing Company, Madras, 1990.
5. A. I. Vogel, Vogel's Text Book of Quantitative Inorg Analysis, 6th Ed., Pearson Ed 2000.

Reference Books

1. J. D. Woolins, Inorganic Experiments, Wiley-VCH Verlag GmbH and Co., 2003.
W. G. Palmer, Experiments in Inorganic Chemistry, Cambridge University Press

DETAILED SYLLABUS OF SEMESTER -II

Course Code	Course Name	Credits
<u>AC 521</u>	<u>INORGANIC CHEMISTRY-II</u>	4
Course Objectives: ➤ To develop an insight into the basic knowledge of inorganic chemistry ➤ To understand the concept of bioinorganic chemistry with mechanism of oxygen transport ➤ To understand role of metal in biological fields. ➤ To understand applications of bioinorganic chemistry		
<u>UNIT I: BIO-INORGANIC CHEMISTRY</u> Occurrence and availability of Inorganic elements in organisms, transport and storage of Inorganic elements, Dose response of an element, biological function of inorganic elements, beneficial and toxic elements, essential and trace metals Siderophore, phyto siderophores, ferritin, transferrin, hemosiderin, biomineralization, assembly of advanced materials e.g. calcium phosphate, calcium carbonate, iron biominerals. Oxygen transport and storage through hemoglobin and myoglobin, Alternative oxygen transport in lower organisms.		
UNIT II: Photosynthesis: Photochemistry, absorption spectra of photosynthetic pigments, photophosphorylation - energy conversion process Role of Alkali and alkaline earth metals in neuro sensation. Ion Channels, ion pumps, magnesium catalysis of phosphate, ubiquitous regulatory role of calcium.		
UNIT III: Biological ligands for metal ions: Macrocyclic, nucleobase, nucleotides and nucleic acids, coordination of metals by protein. Heme and nonheme protein, oxygen uptake, structure and function of haemoglobin, myoglobin, hemocyanin, hemocytin Principle involved and role of various metals viz. Zn, Fe, Cu and Co; carboxypeptidase, carbonic anhydrase, Alcohol dehydrogenase, Zinc Fingeres, other gene regulatory Zinc proteins, cobalamin, mutase activities of coenzyme B12.		
<u>UNIT IV: APPLICATIONS OF BIO-INORGANIC CHEMISTRY</u> Medicinal therapy; metal deficiency and disease, toxic effect of metals, metals used for diagnosis and chemotherapy, gold compound as Anti-Rheumatic agent. Nitrogen cycle;		

biological nitrogen fixation, metalloenzyme in biological nitrogen cycle, molybdenum nitrogenase, other nitrogenase model, Nanoparticles for antimicrobial applications

Course Outcomes

After completing this course, the students will be able to:

- The concept of Bioinorganic Chemistry and its biological applications
- To understand photosynthesis and other photochemical reactions
- Role of bioinorganic chemistry in nature
- Important Applications of Bio-inorganic chemistry

Text Books

1. The Organometallic Chem. of the Transition Metals, Robert H. Crabtree, Wiley 2014
2. Organo transition Metal Chemistry: From Bonding to Catalysis by John F. Hartwig, University Science Books, 2009
3. Organo transition Metal Chemistry, Anthony F. Hill, Royal Society of Chemistry, 1. Tutorial Chemistry Text, 2002. Chapters 1 to 7.
4. Inorganic Chem – Principles of Structure & Reactivity, J E Huheey, Ellen A Keiter &

Reference Books

5. Richard L Keiter, IV Edition(2005)

Course Code	Course Name	Credits
<u>AC 522</u>	<u>ORGANIC CHEMISTRY-II</u>	3
Course Objectives: ➤ To impart advanced knowledge of reactive intermediates, stereochemistry of organic compounds\ pericyclic reactions, heterocyclic compounds and applications in biomolecule ➤ To understand the chemistry of heterocyclic compounds ➤ To understand structure and properties of biomolecules. ➤ To understand the applications of some instrumentation in analysis of organic		
<u>UNIT I: PERICYCLIC REACTIONS AND PHOTOCHEMISTRY</u> Electro cyclic, cyclo-addition and sigma tropic reactions. Orbital correlations – FMO and PMO treatments, Woodward-Hoffmann rule. Photochemistry of alkenes, arenes and carbonyl compounds. Photooxidation and photoreduction. Di- π -methane rearrangement, Barton-McCombie reaction, Norrish type-I and II cleavage reaction.		

UNIT II: HETEROCYCLIC COMPOUNDS

Introduction to heterocyclic compounds and their applications, Structure, preparation, properties and reactions of furan, pyrrole, thiophene, pyridine, indole, quinoline and isoquinoline.

UNIT III: BIOMOLECULES

Structure, properties and reactions of mono- and di-saccharides, physicochemical properties of amino acids, chemical synthesis of peptides, chemical structure determination of peptides and proteins, structural features of proteins, nucleic acids, lipids, steroids, terpenoids, carotenoids, and alkaloids.

UNIT IV: ANALYSIS TECHNIQUES IN ORGANIC CHEMISTRY

Applications of UV-visible, IR, NMR and Mass spectrometry in the structural determination of organic molecules.

Course Outcomes

After completing this course, the students will be able to:

- Understanding of Electro cyclic /cyclo-additions and sigma tropic reactions
- To understand photo-oxidation and photo reduction and related rearrangements
- To understand hetero-cyclic and their applications in bio-molecules and drugs
- To familiarize students in various analysis techniques

Selected Text Books

1. A Guidebook to Mechanism in Organic Chemistry – **Peter Sykes**
2. Organic Chemistry -**Clayden, Greeves, Warren and Wothers**
3. Modern Methods of Organic Synthesis – **William Carruthers, Iain Coldham**
4. Organic Synthesis the disconnection approach – **Stuart Warren**
5. Pericyclic Reactions – R T Morrison, R N Boyd

Reference Books

Organic Photochemistry – James H. Coxon, B. Halton

LIST OF ELECTIVE COURSES FOR III SEMESTER

Course Code	Course Name	Credits
AC 523	MOLECULAR SPECTROSCOPY-I	3
Course Objectives: ➤ Students understand fundamental principles of Spectroscopy and theories involved ➤ Understand the concept of atomic spectra ➤ To understand the concept of group theory ➤ To understand the concept of vibrational spectra		
Basic elements of spectroscopy, Interaction of Radiation with matter, Time dependent perturbation. Einstein coefficients. Integrated absorption coefficients. Transition dipole moments and general selection rules based on symmetry ideas. <u>UNIT I: INTRODUCTION TO MOLECULAR SPECTROSCOPY</u> Rotational spectroscopy of diatomic molecules. Rigid rotor approximation. Determination of bond lengths and/ or atomic masses from microwave spectral data. Effect of isotopic substitution. Non-rigid rotator. Classification of polyatomic molecules. Energy levels and spectra of symmetric top molecules and asymmetric top molecules. First order Stark effect. <u>UNIT II: ATOMIC SPECTRA</u> Characterization of atomic states. Microstate and spin factoring methods. Hund's rules. Derivation of spin and orbital selection rules (based on recursion relations of Legendre polynomials). Spectra of complex atoms. Zeeman and Stark effects. Construction of hybrid orbitals using symmetry aspects. Atomic Spectroscopy: The energies of atomic orbitals; Hydrogen atom spectrum; Orbital and spin angular momenta, total angular momentum; the fine structure of hydrogen atom spectrum; The spectra of complex atoms: Singlet and triplet states; Russell-Saunders coupling; Term Symbols and selection rules. Franck-Condon principle, electronic and Raman spectroscopy of diatomic and polyatomic molecules. <u>UNIT IV: VIBRATIONAL SPECTROSCOPY</u> Homonuclear and heteronuclear diatomic molecules. Extension to polyatomic linear molecules. Derivation of selection rules for diatomic molecules based on Harmonic oscillator approximation. Force constants and amplitudes. A harmonic oscillator. Overtones and combination bands. Introduction to normal coordinate analysis. Dissociation energies from vibrational spectral data. Vibration-rotation spectra, P, Q and R branches. Breakdown of the Born-Oppenheimer approximation. Nuclear spin effect. Symmetry of normal coordinates. Use of Group Theory in assignment of spectra and selection rules for simple molecules.		

Course Outcomes
After completing this course, the students will be able to: ➤ To study understand the principles of atomic and molecular spectroscopy ➤ To understand theory of vibrational spectroscopy
Text Books
<u>BOOKS (MOLECULAR SPECTROSCOPY)</u> 1. Introduction to Spectroscopy, Donald Pavia, 2. Spectrometric Identification of Organic Compounds, R. M. Silverstein, G. C. Bassler and T. C. Morrill, John Wiley & Sons, New York, 5th Ed.1991. 3. Electron Paramagnetic Resonance, Elementary Theory and Practical Applications, Weil, John A, J. R. Bolton, and Wertz, J. E, Wiley-Inter science, New York, (1994). 4. Structural Methods in Inorganic Chemistry, E.A.V. Ebsworth, D.W.H. Rankin, & S. Cradock, 2nd Ed.1991, CRC Press, Boca Raton, Florida, 5. Principles of Fluorescence Spectroscopy, Lackowicz, Plenum Press, (New York,1983)
Reference Books
D. W. Williams and Flemming, Spectroscopic methods of organic compound

Course Code	Course Name	Credits
<u>AC 524</u>	<u>POLYMER CHEMISTRY</u>	3
Course Objectives: ➤ To understand fundamental concepts and techniques in polymer chemistry ➤ To understand reaction mechanism and characterization techniques of polymers ➤ To understand different types of polymers. ➤ Students get knowledge regarding commercial applications of polymers		
<u>UNIT I: FUNDAMENTAL CONCEPTS</u> Functionality - principle of polymerisation - addition, condensation polymerisation - ring opening polymerisation - classification - production from coal tar and petrochemicals - Techniques of polymerisation - gas polymerisation, - bulk, solution, suspension and emulsion - melt condensation. Mechanism of polymerisation and general characteristics - free radical - cationic, anionic and coordination polymerisation (Ziegler-Natta catalyst) auto acceleration - Kinetic chain length - degree of polymerisation, kinetics of polymerisation (Detailed study) - copolymerisation.		

UNIT II: POLYMER CHARACTERISATION

Molecular weight, MWD - M_n , M_w , M_v and M_z - end group analysis - viscometry - osmometry - Light scattering - spectral analysis - Thermal properties – Polymer rheology, Electrical properties, Mechanical and dynamic properties - polymer degradation. Phase transitions of polymers, crystallization and glass transition, mechanism of glass transition, methods of determining T_g .

UNIT III: STUDIES OF INDIVIDUAL POLYMERS

Plastics - polyolefins, polystyrenes, acrylics, polyesters, polyamides, cellulose, polyurethanes, Inorganic polymers, FIR plastics – GR plastics. alkyd resins, epoxy resins - phenolics - Melamine resins - compounding of plastics - rubber - elastomer - vulcanisation, compression mouldings - injection mouldings - lamination. Biopolymers - Biomaterials - medicinal applications of polymers - High temperature and fire-resistant polymers. Polymer concrete - polymer impregnated concrete - conducting polymers - polymeric reagents.

UNIT IV: POLYMER FOR COMMERCIAL APPLICATIONS

Technology of Production, Properties and Applications of Chain growth polymers Polyethylene such as HDPE, MDPE, LDPE, LLDPE, HMWPE, UHMWPE, EVA, crosslinked PE, chlorinated PE, Polypropylene (PP), Polyisobutylene (PIB)), Acrylics (PMMA & PAN), Poly-vinyls like PVC, PVDC & CPVC, Polystyrene & Co-polymer (HIPS, SBR, SAN & ABS), Poly(vinyl acetate).

Course Outcomes

After completing this course, the students will be able to:

- To understand fundamental concepts and techniques in polymer chemistry
- Methods of characterization of polymers.
- learn various important polymers.
- Familiarize polymers having commercial applications

Text Books

1. P.J. Flory, 'Principles of Polymer Chemistry', Cornell Press, (Recent Edition).
2. Jr. Billmeyer, 'Text Book of Polymer Science', Fred, W. John Wiley & Sons, N. York, 1984.
3. Dan Campbell, Richard A. Pethrick, Jim R. White, Polymer Characterization: Physical Techniques, 2nd Edition, CRC Press, 2012.
4. F. Rodrigues, 'Principles of Polymer Systems', M. Elpaw Hill Book Company, 2nd Ed., 1982.
5. K.J. Saunders, 'Organic Polymer Chemistry', Chapman & Hall, London, 1973.

Reference Books

Sabu Thomas & Dominique Durand, Handbook of Biopolymer-Based Materials: From Blends and Composites to Gels and Complex Networks, Wiley – VCH, 2013.

Course Code	Course Name	Credits
<u>AC- 525</u>	<u>RECENT ADVANCES IN CHEMISTRY</u>	3
Course Objectives: ➤ To understand background and discoveries of recent advances chemical technologies ➤ To understand the concept of green chemistry and its methods synthesis ➤ To understand the development in biochemistry and biotechnology ➤ To understand the concept of smart materials and applications.		
<u>UNIT-1. INTRODUCTION</u> Background and eminent discoveries in Chemical Technology, Frontiers in Electrochemistry: Equilibrium properties of electrolytes, electrode potential, electro analytical techniques.		
<u>UNIT-2 : GREEN CHEMISTRY</u> Principals of green chemistry, sustainability, selected examples of green synthesis.		
<u>UNIT-3: BIOCHEMISTRY & BIOTECHNOLOGY:</u> Cell Biology and Physiology, Bioenergetics, Industrial Biotechnology.		
<u>UNIT-4. CHEMISTRY OF SMART MATERIALS:</u> Smart materials, their properties, distribution by type chemistry of macromolecules, phase change materials		
Course Outcomes		
After completing this course, the students will be able to: ➤ To familiarize students in important discoveries of chemical technologies ➤ To understand electrochemical techniques ➤ To understand biochemistry and biotechnology ➤ To understand the chemistry of smart materials		
Text Books		
a. Electrochemistry for Chemists, Sawyer, Sobkowiak, & Roberts, John Wiley, 1995. b. Concepts in Transition Metal Chemistry, Crabb, Eleanor, Moore, Elaine, Smart, Lesley E.RSC Publishing, 2010 c. Highlights in Bioorganic Chemistry, Carsten Schmuck, Helma Wennemers, Wiley-VCH, 2004.		
Reference Books		
Essentials of Pharmaceutical Chemistry, D. Cairns 5. Intelligent Materials, M. Shahinpoor, H.-J. Schneider, RSC, 2008		

Course Code	Course Name	Credits
AC 526	<u>FORENSIC CHEMISTRY AND TOXICOLOGY</u>	3
Course Objectives: ➤ To understand the concept of forensic chemistry ➤ To understand the standard methods and general instrumental techniques Understand the concept of explosives and classifications. ➤ To understand toxicology and pharmacology along with drugs types and classifications		
UNIT I: Introduction to Forensic chemistry, sampling of chemical evidences, presumptive, screening (colour/ spot test), inorganic analysis. Chemistry of fire, searching of fire scene, collection, preservation and examination. Adulteration in Petroleum products. Standard methods and general instrumental techniques based on Spectroscopy (UV, PL, Atomic, Raman, IR, xrd), Electrochemistry (Potentio, conducto, Voltammetry) , Chromatography (GC,TLC, HPLC), analysis of beverages- alcoholic and non-alcoholic, country made liquor and medicinal preparations containing alcohol as constituents. Significance of alcohol in breath and breath screening devices. Analysis of Fertilizers/ insecticides/ pesticides/ biocides. UNIT II: Explosives Classification of explosives, synthesis and characteristics of Tri-nitro toluene (TNT), Pentaerythritol tetranitrate (PETN) and Research and Development Explosives (RDX). Explosion process, blast waves, searching of scene of explosion. Post blast residue collection and analysis, blast injuries and detection of hidden explosives. Improvised explosive devices. UNIT III: Toxicology and Pharmacology Definition, classification of poisons- organic, inorganic, metallic, non-metallic etc. Acute and chronic poisoning, Accidental, homicidal and suicidal poisoning, Extraction and identification of commonly used poisons. Dosage, Frequency, Route of administration, Absorption, distribution and metabolism and factors affecting metabolism and excretion. Toxicological techniques. UNIT IV: Drugs of Abuse Natural and synthetic drugs of abuse. Drug dependence, classification of drugs- Narcotics, Hallucinogens, Depressants, Stimulants, Anabolic steroids. Psychotropic and Psychedelic drugs of abuse. Field and laboratory tests of drugs of abuse. Instrumental methods of analysis, collection, preservation and transportation of drug evidences		
Course Outcome ➤ Students get knowledge regarding forensic chemistry ➤ Knowledge of methods and general instrumental techniques based on Spectroscopy ➤ Understand the concept of explosives and classifications. ➤ Clear the concept of toxicology and pharmacology along with drugs types and classifications.		

References:

1. Niesink, RJM; Toxicology- Principles and Applications, CRC Press, 1996
2. Modi, JP, Textbook of Medical Jurisprudence & Toxicology, N.M. Tripathi Pub, 2001
3. Chadha, PV; Handbook of Forensic Medicine & Toxicology, Jaypee Brothers, New Delhi, 2004
4. Morrison R.T and Boyd R. N; Organic Chemistry 6th Ed Prentice Hall, 2003
5. Lab Procedure Manual-Petroleum Products, Dir. of Forensic Science, MHA, Govt. of India, 2005
6. Working Procedure Manual on Chemistry; Directorate of Forensic Science MHA Govt. of India
7. Bureau of Indian Standard Specifications related to Alcohols and Petroleum Products.
7. Standard Methods of Chemical Analysis, 6th Ed. Van Nostrand Reinhold, New York, 1969

- The students can optd **ANY THREE Professional Electives (PE)** from the program of Applied Chemistry Department as well as all the program of another department of DIAT (with equal credit ONLY)
- Also, can optd online courses from NPTEL, MOOC. SWAYAM (equal credit)
- Maximum of 6 credits to be awarded for Professional Electives (Approved by BoS) for ONLINE courses NEPTL during II and III Semester.
- On Job Training (OJT) evaluation to be conducted at the end of first year.

DETAILED SYLLABUS OF SEMESTER -III

Course Code	Course Name	Credits
<u>AC 531</u>	<u>PHYSICAL CHEMISTRY-II</u>	3
Course Objectives: To apply the knowledge and understanding in the areas of solid-state chemistry To understand concept of chemical kinetics To understand surface chemistry for solving existing challenges faced in various chemical and industrial areas		
<u>UNIT I: CHEMICAL KINETICS</u> Elementary, parallel, opposing and consecutive reactions. Steady state approximation. Mechanisms of complex reactions. Uni-molecular reactions. Potential energy surfaces and classical, Activated Complex Theory, Potential energy surfaces- attractive and repulsive forces, Chain reactions and oscillatory reactions, Photochemical reactions. Enzyme kinetics: Michaelis-Menten mechanism- single and double intermediates, Enzyme inhibition- reversibility and products inhibition, Molecular beams, principle of crossed-molecular beams. Molecular encounters and principle parameters, e.g. Impact parameter,		

Collision cross-section, Reaction cross section and relation between reaction cross-section and reaction rate (single velocity). Dependence of collisional cross-section on translational energy. Probing the transition state, Dynamics of barrier-less chemical kinetics in solution, dynamics of uni-molecular reactions. Luminescence and energy transfer processes, study of kinetics by stopped-flow technique, relaxation method, flash photolysis and magnetic resonance method. Kinetics of solidstate reactions.

UNIT II: SURFACE CHEMISTRY

Surface tension, Capillary action, Pressure difference across curved surface (Laplace equation), Vapour pressure of droplets (Kelvin equation), Gibbs adsorption isotherm, BET adsorption isotherm, Surface films (Electro-kinetic phenomenon), Catalytic activity at surfaces. Catalysis on metal surfaces, Metal oxide surfaces. General characteristics of catalytic reactions, Acid-base catalysis, Enzyme catalysis, Mechanism and kinetics of enzyme-catalysed reactions, Michaelis-Menten equation, Heterogeneous catalysis, Surface reactions, Autocatalysis and Oscillatory reactions. Surface active agents, Classification of Surface active agents, Co-surfactants, Micellization, Microemulsions, Aggregate structures of surfactants, Critical Micellar Concentration, Surfactant packing parameter, Factors affecting the CMC of surfactants, Counter ion binding to micelles, Hydrophobic interaction, Thermodynamics of micellization, Mass action models, Solubilization and Phase diagram of ternary microemulsion system

UNIT III: SPECTROSCOPY

Atomic Spectroscopy: The energies of atomic orbitals; Hydrogen atom spectrum; Orbital and spin angular momenta, total angular momentum; the fine structure of hydrogen atom spectrum; the spectra of alkali metal atoms. The spectra of complex atoms: Singlet and triplet states; Franck-Condon principle, electronic and Raman spectroscopy of diatomic and polyatomic molecules. Relationship of transition moment integral with molar extinction coefficient and oscillator strength electronic spectra of polyatomic molecules. Electronic spectra of transition metals Emission spectra: radiative and non-radiative decay, internal conversion, spectra of transition, metal complexes, charge-transfer spectra.

Course Outcomes

After completing this course, the students will be able to:
➤ Understanding rate laws based on Chemical Kinetics
➤ Understanding different aspects of surface chemistry
➤ To understand various phenomena of group theory and spectroscopy
Text Books
1.Chemical Applications of Group Theory – F. Albert Cotton
2.Fundamentals of Molecular Spectroscopy – Colin N. Banwell
Reference Books
Physical Methods – Russel S. Drago

Course Code	Course Name	Credits
<u>AC 532</u>	<u>INDUSTRIAL CHEMISTRY</u>	3
Course Objectives: ➤ To understand the scalability of laboratory reactions in Industry ➤ To understand proper operations and safety in industry ➤ To understand reduction process by use of ammonia ➤ To understand different types of reactions in industry		
<u>UNIT I: CHEMICAL INDUSTRY</u> Introduction, Chemical production, Raw materials and their sources, Parameters of Chemical Industry, Plant location, Safety, Construction of plant, Management for productivity and creativity, Training for plant procedure and labour, Chemical process technology, Important chemical processes, Classification of chemical reactions, Batch and continuous operations, Industrial chemical reactions, Conversion, Selectivity and Yield, From Chemistry Laboratory to Industrial Scale		
<u>UNIT II: INDUSTRIAL PROCESSES AND THEIR SAFETY:</u> Introduction, Unit operations- Conveying, Crystallization, Distillation, Drying, Evaporation, Filtration, Leaching, Liquid-liquid extraction, Membrane separation, Particle size reduction and enlargements, Solid -solid separation. Introduction, Industrial unit processes- Definition and examples of Alkylation, Amination by amino lysis, Calcination, Carbonylation, Double decomposition, Esterification, Halogenation, Hydro formulation, Hydrolysis, Nitration, Oxidation, Polymerisation, Sulphonation.		

UNIT III: AMINATION BY REDUCTION:

Introduction and definition, Methods of reduction, Metal and acid Reductions, Metal and alkali reductions, Amination by amino-lysis, aminating agents, physical and chemical factors affecting amino lysis, manufacture of aniline by reduction of nitrobenzene, p-phenylenediamine, aniline by continuous ammonolysis.

UNIT: IV IMPORTANT INDUSTRIAL REACTIONS

- A. **INTRODUCTION AND TYPES** of Alkylation, alkylating agents, factors controlling alkylation, equipment for alkylation, alkylation methods for i) Alkyl-aryl sulphonates, ii) Ethylbenzene, iii) Dimethylaniline.
- B. **HYDROLYSIS:** Definition and scope, hydrolyzing agents, materials susceptible to hydrolysis, kinetics, thermodynamics and mechanisms of hydrolysis, Equipment for hydrolysis, Technical operations involving hydrolysis.
- C. **OXIDATION:** Liquid and vapour phase oxidations, apparatus for Oxidation, technical oxidation of acetaldehyde, iso-propyl alcohol, naphthalene, and naphthalene sulphonate acid. Esterification: Esterification of organic acids and derivatives, esters by addition.
- D. **HYDROGENATION:** Catalytic hydrogenation, Apparatus, Industrial processes, Hydrogenation of fatty oils, Synthesis of methanol. Nitration: Introduction, Nitrating reagents, Aromatic nitration, Nitration of paraffinic hydrocarbons, nitrate esters, N-nitro-compounds, process equipment for technical nitration, Mixed acid nitration,

UNIT V : Chemical biology, artificial intelligence in industrial chemistry etc.

Course Outcomes

After completing this course, the students will be able to:

- To understand the scalability of laboratory reactions in Industry
- To understand operations and safety in Industrial reactions
- In-depth study of Amination/Alkylation reactions

Text Books

1. Unit Processes in Organic Synthesis- P. H. Groggins, Tata McGraw-Hill, 5th Edition, New Delhi, 2010.
2. Dryden's Outline of Chemical Technology, M. Gopal Rao, Marshall Sittig East-West Press Pvt. Ltd., 3rd Edition, 2014.
3. Chemical Process Industries- B. Shreve., Tata McGraw Hill, New Delhi, 2012.
4. Comprehensive Industrial Chemistry, P. G. More, Pragati Edition, Meerut, 2010.

Reference Books

1. Encyclopaedia of Chemical Technology, Kirk and Othmer, John Wiley & Sons, 2000

SYLLLABUS OF ELECTIVE COURSES FOR III SEMESTER

Course Code	Course Name	Credits
AC 533	ORGANO-METALLIC CHEMISTRY AND CATALYSIS	3

Course Objectives:

- To understand the basic of organometallics and their synthesis.
- To understand bonding, properties and their applications
- To understand the role of organometallic reagent in organic synthesis.
- To understand importance of organo metallic reagent

UNIT I: ORGANOMETALLICS

18-Electron rule, Oxidation state, co-ordination number and geometry. Effect of complexation with different metals (4d and 5d); Alkyls and hydrides: alkyls and aryls (metal alkyls stabilized carbanion, β -elimination, stable alkyls, agostic alkyls, reductive elimination, preparation of metal allyls). metal hydrides: characterization, synthesis, reactions, bridging hydrides.

UNIT II: SYNTHESIS, BONDING, PROPERTIES & APPLICATIONS OF ORGANOMETALLICS

Pi complexes, synthesis, bonding. Properties and application of alkenes and alkynes, allyls, diene, cyclopentadiene, dienyl, arenes. Distinctive organometallic Reactions - Addition and abstraction: Nucleophilic addition to CO, Nucleophilic addition to polynes and polyenyls, nucleophilic abstraction in hydrides, acyls, electrophilic addition and abstraction, single electron transfer and radical reactions, Oxidative – Addition reactions, Insertion reaction – at MC bond & M-H bond, Trans-metallation reaction and Cyclization reaction, Ring Expansion reaction, Condensation reaction, Sigma-pi rearrangement reaction, Ligand & Metal exchange reactions.

UNIT III: ORGANOMETALLIC REAGENTS IN ORGANIC SYNTHESIS

Alkene isomerisation, hydrogenation, hydroformylation, hydrocyanation, hydroboration, coupling reaction. Carbon-carbon bond formation through coupling reactions – Heck,

Suzuki, Stille, Sonogoshira, Negishi, Kumada, Hiyama, Tsuji-Trost, olefin metathesis and McMurry.

UNIT-IV:IMPORTANT ORGANOMETALLIC REACTIONS

Homogeneous catalysis –Catalytic applications of organometallic complexes - Alkene hydrogenation, Synthesis gas (H₂/CO), Hydroformylation, Mosanto-acetic acid process, Wacker- Schmidt process and Ziegler-Natta catalysis. Bioorganometallic chemistry and surface organometallic chemistry.

Course Outcomes

After completing this course, the students will be able to:

- To understand fundamentals of Organometallic chemistry
- To familiarize with the synthesis, property studies and application of Organometallic chemistry
- Applications of Organometallic reagents in Organic Synthesis

Text Books

1. Organometallics: A concise Introduction, Ch.Elshebroicn and A Salzer, VCH, 2006.
2. transition Metal Chemistry: Applications to Organic Synthesis, S.G. Davies, Pergamon 1982.

Reference Books

Basic Organometallic Chemistry, Anil Elias

Course Code	Course Name	Credits
<u>AC 534</u>	<u>MOLECULAR SPECTROSCOPY II</u>	3
Course Objectives: ➤ To understand and apply various spectroscopic techniques for characterization. ➤ To understand concept of electronic spectroscopy ➤ To understand difference between various spectroscopic techniques.		
<u>UNIT I: RAMAN SPECTROSCOPY</u> Stokes and anti-Stokes lines. Polarizability of molecules. Rotational and Vibrational Raman spectroscopy. Selection rules. Polarization of Raman lines.		
<u>UNIT II: ELECTRONIC SPECTROSCOPY</u> Diatomic molecules. Selection rules. Breakdown of selection rules. Franck-Condon factors. Dissociation energies. Photoelectron spectroscopy of diatomic (N ₂) and simple polyatomic molecules (H ₂ O, formaldehyde). Adiabatic and vertical ionization energies. Koopmans' theorem. Qualitative ideas of solvent effects- viscosity, polarity, hydrogen bonding.		

UNIT III: NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY (NMR)

General introduction and definition; chemical shift; spin-spin interaction; shielding mechanism of measurement; chemical shift values and correlation for protons bonded to carbons [aliphatic; olefinic; aldehydic and aromatic] and other nuclei [alcohols; phenols; enols; acids; amines; amides and mercaptans]; chemical exchange; effect of deuteration; complex spin-spin interaction between two; three; four; and five nuclei [first order spectra]; virtual coupling. Stereochemistry; hindered rotation; Karplus curve variation of coupling constant with dihedral angle. Application of ^1H and ^{13}C NMR spectroscopy including COSY, NOESY, NOE techniques in the structural determination of complex organic systems. Application in conformational analysis. Multinuclear NMR of various inorganic and organometallic compounds. Data Interpretation, case studies.

UNIT IV: ELECTRON SPIN RESONANCE

Electron spin and Magnetic moment, Resonance condition in ESR and significance of 'g' value. ESR spectra of organic free radicals, Electron Exchange reactions, applications of ESR.

UNIT V: PRINCIPLES OF MOSSBAUER SPECTROSCOPY

Basic principles, a chirality of nucleus, Isomer shifts. Quadrupole and Nuclear Zeeman splittings. Applications in structure determination.

UNIT VI: ELECTRIC AND MAGNETIC PROPERTIES OF MOLECULES

Polarizability, polarization of a molecule in an electric field (electronic, atomic and orientation polarization), Clausius-Mossotti equation, variation of molar polarization with temperature: Debye equation, bond moments, dipole moments and molecular structure. Magnetic susceptibility, molecular interpretations of diamagnetism and paramagnetism, Ferro, ferri and antiferromagnetic behavior, Curie and Neel temperatures, Measurements of magnetic susceptibility by Faraday and Gouy Technique.

Course Outcomes

After completing this course, the students will be able to:

- To understand the principles of RAMAN spectroscopy
- To understand the principles of electronic spectroscopy
- To understand the principles of NMR spectroscopy
- To understand the principles of Mossbauer spectroscopy

Text Books

1. C. N. Banwell and McCagh, "Fundamentals of Molecular Spectroscopy", Fourth Edition, Tata McGraw Hill Publishing Co.Ltd, 1994.
2. Donald L. Pavia, Gary M. Lampman, George S. Kriz and James A. Vyvyan, "Introduction to Spectroscopy", Fourth Edition, Cengage Learning, 2009.
3. W. Kemp, "Organic Spectroscopy", Second Edition, ELBS MacMillan, 1987.

Reference Books

AC 535	DEFENCE CHEMISTRY	3
Course Objectives: ➤ To understand concept of Defence chemistry ➤ To understand the chemistry behind the explosive and pyro techniques. ➤ To understand the concept of nuclear energy in defence. ➤ To understand chemical and biological warfare agents		
UNIT I: Explosives: Introduction, Classification, Nature of Explosives, Burning, Deflagration & Detonation, Initiation theories of explosives, Thermochemistry of explosives, various performance parameters of explosives, Propellants: Introduction, Rocket & Gun Propellants, Pyrotechnics: Definition, classification, Ingredient, Various compositions UNIT II : Polymers and Nanocomposite for defence applications: Metal replacement polymers., High Performance Engineering Polymers, Lightweight polymers, Chemical Resistant polymers. UNIT III : High Strength Materials, alloys for defence applications. UNIT IV : Nuclear Science: Structure of nucleus, Mass defect, Binding energy, Nuclear reactions, fission & Fusion nuclear reactions, Controlled & uncontrolled release of nuclear energy, Concepts of critical mass & critical volume UNIT V: Chemical & Biological Weapons: Different chemical and Biological warfare agents & their effects; Protection against biological, chemical warfare agents Text/References: 1) Principles/Effects & Sensitivity, 1994, C.S. Grace, Brasey series 2) Chemical warfare agents, 1992, S.M.Somai 3) Biological weapons, 1999, Joshua Lederberg		
Course Outcomes		
After completing this course, the students will be able to: ➤ Study of chemistry of High Energy Materials ➤ To understand the applications of polymers and nanocomposites in defence ➤ To familiarize with High strength materials ➤ To understand NBC and their remediation		
Text Books		

1. J P Agrawal: High Energy Materials, Wiley VCH, 2012
2. N. Ramdani: Polymer Nanocomposites for advanced Aerospace and Military Applications, IGI Global, 2019.
Reference Books
1. NBC: Nuclear, Biological, and Chemical Warfare on the Modern Battlefield John Norris, Will Fowler, 1997.

Course Code	Course Name	Credits
<u>AC-536</u>	PAINTS, PIGMENTS AND VARNISHES	3
Course Objectives ➤ To understand the basic concept of paints, pigment ➤ To understand classifications of paints and pigment ➤ To understand basic concept, varnishes. ➤ To understand the various applications		
UNIT I : Fundamental of PAINTS: - General, Classification, Theories for dye Structure, Principle Applications., Description of individual of class and synthesis of some commercial dyes. Dyeing processes of textiles -Pre-treatment of textile fibres, dyeing methods for various textiles, Textile finishes and Textile auxiliaries. Non textile dyes: Leather, Fur, Hair, Food, Ink, Photographic, indicator dyes.Environmental and health impacts of paints and varnishes. UNIT II : PAINTS/ DYES for electro optical application- Molecular Orbital design, Synthesis and characteristics of functional dyes. Near infrared absorption (NIR) dyes: Introduction, Cyanine type chromophores, donar-acceptor chomophores, and applications. Colorants for high technology, Photocopying, LCD, Printing, Dye Sensitizer Solar Cells Photodynamic Therapy, Fluorescent Brightening Agents UNIT IV Pigments- Pigments general idea, distinguish between dyes and pigments, important characteristics of organic pigments, Toners, Lakes, Classification of organic pigments with suitable examples, i.e. Ionic pigments-Lake of acid and basic dyes. Non-ionic pigments-Azo, Indigoid, Anthraquinone, Quinacridone, Phthalocyanine (Copper phthalocyanine)..		

UNIT V : Vanishes - Definition, different types of classification, synthesis, Characterization and application.

Course Outcome

- Study of chemistry of paints, pigment and varnishes
- To understand the applications of pigment and paints
- To understand some chemistry and classifications of paints and varnishes
- To understand the concept of optical brighteners

References:

1. Foye's principles of medicinal chemistry. 6th Edition, Edited by Davis William & Thomas Lemke, Indian edition by B I Publication Pvt Ltd, Lippincott Williams & Wilkins.
2. Text book of organic medicinal & pharmaceutical chemistry. Wilson & Gisvold, 11th Edition by John H Block, John M Beale Jr.
3. Medicinal chemistry. Ashutosh Kar, New Age International Pvt. Ltd Publisher. 4th edition.
4. The organic chemistry of drug design & drug action. 2nd ed. By Richard B Silvermann, Academic Press.
5. Chemistry of Synthetic Dyes, Vol I – VIII, Venkatraman K., Academic Press 1972
6. The Chemistry of Synthetic Dyes and Pigments, Lubs H.A., Robert E Krieger Publishing Company, NY ,1995
7. Chemistry of Dyes and Principles of Dyeing, Shenai V.A., Sevak Publications, 1973

Course Code	Course Name	Credits
<u>AC- 537</u>	DRUG DESIGN AND PHARMACOLOGY	3
Course Objectives: ➤ Explain the fundamental principles of pharmacology ➤ Describe the concepts of toxicology and biotransformation's. ➤ To understand various routes of drugs administration ➤ To understand the concept of pharmacology.		
Unit I : General Introduction to Drugs – Definition of a drug, sources of drugs, requirements of an ideal drug, classification of drugs (based on therapeutic action), Nomenclature of drugs: Generic name, Brand name, Systematic name, Definition of the following medicinal terms: Pharmacokinetics, Pharmacodynamics, Prodrug, Half – life, LD ₅₀ , ED ₅₀ , GI ₅₀ Therapeutic Index, Brief idea of the following terms: Receptors, Agonists, Antagonists, Drug-receptor interaction, Drug Potency,		

Bioavailability, Drug toxicity, Drug addiction, Spurious Drugs, Misbranded Drugs, Adulterated Drugs, Pharmacopoeia.

Unit II : Routes of Drug Administration and Dosage Forms, Oral and Parenteral routes with advantages and disadvantages. Formulations & combination formulation, Different dosage forms (including Patches & Adhesives, emphasis on sustained release formulations and enteric coated tablets). Drugs for Respiratory System General idea of: Expectorants; Mucolytics; Bronchodilators; Decongestants; Antitussives

UNIT III: Drugs and Environmental Aspects, Impact of Pharma-industry on environment, , International regulation for human experimentation with reference to: “The Nuremberg Code” and “The Helsinki Declaration”.

UNIT IV: Pharmacology: Drugs and Drug Targets - Enzymes: active sites, mechanism of catalysis, Enzyme inhibitors, Enzyme selectivity, and Receptors ligand gated ionic channels, G-Protein coupled receptors, and Kinase linked receptors. Carrier Proteins, Structural Proteins, Nucleic acids, Lipids and carbohydrates and DNA as drug targets, Pharmacokinetic Principles: absorption, distribution, metabolism and excretion of drugs. Dose of drugs and routes of administration. Drug dosing, drug half-life, Steady state concentration, Drug tolerance, Bioavailability, Drug delivery.

Course Outcomes

- Students understand concept of drugs and pharmacology
- Understand various routes of drug administrations.
- Under stand the various environmental aspects of drugs

Reference

1. Text book of organic medicinal & pharmaceutical chemistry. Wilson & Gisovolds, 11th Edition by John H Block, John M Beale Jr.
2. Medicinal chemistry. Ashutosh Kar, New Age International Pvt. Ltd Publisher. 4th edition.
3. Burger's Medicinal Chemistry, Drug Discovery and Development. Abraham and Rotella. Wiley
4. Medicinal chemistry. Ashutosh Kar, New Age International Pvt. Ltd Publisher. 4th edition.
5. Medicinal chemistry. V.K. Ahluwalia and Madhu Chopra, CRC Press.
6. Principle of medicinal chemistry. Vol 1 & 2 S. S. Kadam, K. R. Mahadik, K. G. Bothara
7. The Art of Drug synthesis. Johnson and Li. Wiley, 2007.

- The students can opt **ANY THREE Professional Electives** from the Applied Chemistry Department as well as all the courses of another department of DIAT (with equal credit ONLY)
- Also, can opt online courses from NPTEL, MOOC. SWAYAM (equal credit)
- Maximum of 6 credits to be awarded for Professional Electives (Approved by BoS) for ONLINE courses NEPTL during II and III Semester.

M. Sc. Applied Physics
(Photonics)

M. Sc. Applied Physics (Photonics)

One of the greatest scientific discoveries of the twentieth century that has led to technological advancement touching all aspects of human life is the LASER. Applications of lasers range from medical applications, communications, and industrial applications to military applications. An understanding of laser technology is essential for an engineer working in many of the present-day cutting-edge technologies. The aim of this program is to train students in the field of lasers, fiber optics, electro-optics, and photonics that would enable them to meet the challenges in this rapidly developing field.

Stakeholders:

- (i) Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments
- (ii) Graduates in the relevant field of science/technology from recognized Universities across the country.

Eligibility for Students:

The candidate should possess Bachelor's degree or equivalent in Physics, Applied Physics, Engineering Physics, Electronic Science, Photonics, Optics, Material Science, Instrumentation Science or any equivalent branch

OR

B. Tech. (Any discipline)

Organization: The M. Sc. programme is of four-semester duration. In each of the first three semesters, there are six theory courses and one laboratory course. There will be three continuous evaluation examinations and a final semester examination for every course. At the end of the final semester, the student submits a dissertation and makes a presentation about the work carried out by him/her on the project, which is evaluated by the Internal and External examiners. The course syllabus is updated periodically to keep pace with contemporary technological advancements.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO1: The M. Sc. in Photonics Programme aims at developing skilled human resources in the field of Optics, lasers, Electro-optics and overall Photonics. It will ensure the understanding of applied optics, physics and engineering laser technology, fiber optics, semiconductor photonic

devices, laser systems and its various applications, catering to the emerging multidisciplinary problems faced by defence industry and civilization.

PEO2: With a focus on the DRDO requirements, the students will be trained to use their knowledge for the benefit of society and made aware of their social duty. This will enable them to pursue career in research, academics and industry.

PEO3: At the end of the Programme the officer or student should be able to undertake state of the art R&D in lasers and electro-optic systems and competitively work towards development of the latest technology in line with national programmes like Make in India.

PROGRAMME OUTCOMES (POs)

- PO1 Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- PO2 Problem Analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.
- PO3 Design/Development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- PO4 Conduct Investigations of Complex Problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions for complex problems.
- PO5 Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and Modeling to complex engineering activities with an understanding of the limitations.
- PO6 The Engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Sc. Applied Physics (Photonics) Programme, graduates will be able to

PSO1: The M. Sc. in Photonics aims at developing a skilled knowledgeable Human task force in the field of Photonics serving the needs of the Defence Research and Development Organization & Tri – services (Army, Navy & Air force), Coast Guard, DGQA, DQA, Defence Public Sector units, in addition to the civilians in general. After completing M. Sc. course, the students develop an ability to carry out independent research in the area of optical devices.

PSO2: The dissertation work of the M. Sc. students leads to publications in high-impact international journals which trains them in technical documentation and report writing.

PSO3: The goal of the M. Sc. in Photonics course is to generate highly competent human resources in the areas of laser development, electro-optic systems, fibre optics, applied optics, and computational photonics.**M.Sc. Applied Physics (Photonics) Program Structure:**

PSC: Program Specific Core PSL: Program Specific Lab PE: Professional Elective

SEMESTER I

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-1	AP 501	Quantum Mechanics	3	1	4
2	PSC-2	AP 502	Electromagnetic Wave Theory	3	1	4
3	PSC-3	AP 503	Fundamentals of Lasers	3	0	3
4	PSC-4	AP 614	Optical Electronics	3	0	3
5	PSL	AP 504L	Photonics Lab	0	4	2
6	PGC	RM-501	Research Methodology	2	0	4
			Total			20

SEMESTER II

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-5	AP 505	Solid State Physics	3	1	4
2	PSC-6	AP 621	Fiber Optic devices and systems	3	1	4
3	PE-I	AP XXX	Elective 1	3	0	3
4	PE-II	AP XXX	Elective 2	3	0	3
5	PSL/PSC/PE	AP 506L	Photonics and Electronics Lab	0	4	2
6	OJT/FP	AP 507 - OJT	On Job Training/Field Project (120 Hrs)	0	0	4
			Total			20

SEMESTER III

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-7	AP 508	Semiconductor Optoelectronic Devices	3	1	4
2	PSC-8	EE 620	System on Chip and Embedded Systems	3	0	3
3	PE - III	AP XXX		3	0	3
4	PE - IV	AP XXX		3	0	3
5	PE - V	AP XXX		0	0	3
6		RP 541	Project Phase -I		12	6
			Total			22

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	RP 542	Project Phase-II			18
		Total			18

List of Subjects (Applicable for Sem - II):

S.No.	Course Code	Course
1.	AP 617	Computational Photonics
2.	AP 619	THz Device and Applications

3.	AP 620	Nanophotonics
4.		High Power Fiber lasers
	Open Elective/ MOOC Course (The course names are only indicative to guide the student. Students have the choice to take a course other than those listed, as per department guidance)	1. RF Photonics 2. Nonlinear Optics 3. Quantum Optics 4. Applied Optics 5. Bio photonics 6. Python programming 7. Cyber Security

List of Electives/Open Electives (Applicable for Sem - III):

Sr. No.	Course Code	Course
1	AP 602	Technology & Packaging of MEMS
2		
3	Open Elective/ MOOC Course (The course names are only indicative to guide the student. Students have the choice to take a course other than those listed, as per department guidance.)	1. Introduction to Nanoscience and Nanotechnology 2. Nonlinear Optics 3. Quantum Optics 4. Applied Optics 5. Bio photonics 6. Data Science 7. Machine learning 8. Indian Knowledge System
	The electives and other Core Courses offered in the 2 nd semester by the other departments may be opted by the students on consultation with the course OIC/Department.	
	A maximum of 6 Credits can be opted by students as Professional Electives from the list of Online Courses on NPTEL/SWAYAM, which are aligned with the program may be opted by the students on consultation with the course OIC/Department.	

CORE Courses-Semester I			
Subject Code	AP 501		
Subject Title	Quantum Mechanics		
Credit	04		
Teaching Scheme	Lectures: 03 hours/week + 1 hour tutorial		
Evaluation Pattern	4. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 5. One Final Evaluation at the End of the Term 50 Marks 6. Assignments & Term Work Evaluations: 10 Marks		
Total Marks	100 Marks		
Pre-requisite	None		
About the Course	This course provides a foundational understanding of Quantum Mechanics, essential for students in physics and engineering disciplines working with atomic, molecular, and photonic systems. It introduces the mathematical formalism of quantum theory and its physical interpretations, enabling students to analyze simple quantum systems such as potential wells, harmonic oscillators, and one-electron atoms. Additionally, it covers quantum statistics and forms the basis for understanding lasers and modern quantum technologies		
Course Objectives	By the end of this course, the students will be able to: • Understand the fundamental postulates of quantum mechanics and how they differ from classical physics. • Formulate and solve the Schrödinger equation for various potential problems in one and three dimensions. • Apply the formalism of quantum mechanics, including Hilbert spaces, operators, and Dirac notation. • Analyze atomic systems, such as the hydrogen atom, using appropriate mathematical tools. • Explore the principles of quantum statistics and their role in physical systems involving indistinguishable particles. • Relate quantum mechanical principles to practical systems such as lasers, optical devices, and semiconductor physics.		
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create		
CO Title		Level	Descriptor
CO1:	Explain core concepts of thermal radiation, Planck's postulates, and	2	Understand

		Schrödinger's equation.							
	CO2:	Solve quantum systems such as potential wells and harmonic oscillators using analytical techniques.	3	Apply					
	CO3:	Apply Dirac notation, operator algebra, and statistical interpretation in solving quantum mechanical problems.	4, 5	Apply/Analyze					
	CO4:	Analyze hydrogen-like atoms and interpret eigenvalue problems in three-dimensional quantum systems.	4	Analyze					
	CO5:	Explain and apply the principles of quantum statistics and their applications in quantum devices.	2, 3	Understand/Apply0020					
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics								
		PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
	CO1	3	2	-	1		3	1	2
	CO2	3	3	2	2		3	1	2
	CO3	3	3	-	2		3	1	2
	CO4	3	3	-	2		3	1	2
	CO5	3	2	-	2	1	3	1	2
Syllabus Details:									
Unit 1	Introduction: Thermal radiation, Plank’s postulates, The Schrödinger equation, Statistical interpretation, probability, normalization, momentum, the uncertainty principle			Text Book-1, Ch- 1 Text Book 2 Chapter 1		10 Hrs		CO1	
Unit 2	Time Independent Schrödinger: stationary states, infinite square well, harmonic oscillator, free particle, delta function potential, finite square well			Text Book-2 Chapter 2		9 Hrs		CO2	
Unit 3	Formalism: Hilbert’s space, observables, eigen function of Hermitian operator, statistical interpretation, Dirac notation			Book 1 Ch-2 Book 2 Ch-3		9 Hrs		CO3	

Unit 4	One electron atoms: solution of Schrödinger equation in 3D, eigen values, quantum numbers, and degeneracy, orbital angular	Text Book 1 CH-4	9 Hrs	CO4
Unit 5	Quantum statistics: indistinguishability and quantum statistics, quantum distribution functions, Boltzmann distribution as an approximation to quantum distributions, The Lasers	Text Book 1 Ch-8 Reference Book 1	8 Hrs	CO5
Unit 6	Quantum Mechanics in Modern Applications Introduction to Quantum Entanglement and Bell's Inequality Quantum Tunneling and its Applications (e.g., Tunnel Diode, STM) Basics of Quantum Computing: Qubits, Superposition, and Quantum Gates Quantum Cryptography and Quantum Teleportation (Introductory Concepts) Quantum Dots and Nano-scale Systems	Text Book 1 Reference Book 1	9 Hrs	CO5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. Zettili, Nouredine. "Quantum mechanics: concepts and applications." John Wiley and Sons, Ltd., Publishing 2nd Ed. (2009) 4. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing Limited			
Reference Book (Should Know) Ref. as (Rx) in	3. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing 4. Beiser, Arthur. Concepts of modern physics. 2003.			

the Syllabus	

CORE Courses-Semester I				
Subject Code	AP 502			
Subject Title	Electromagnetic Wave Theory			
Credit	04			
Teaching Scheme	Lectures: 03 hours/week			
Evaluation Pattern	4. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 5. One Final Evaluation at the End of the Term 50 Marks 6. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks			
Total Marks	100 Marks			
Pre-requisite	Basic physics knowledge			
About the Course				
Course Objectives				
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create			
CO Title				
	CO1	Understand the basic concepts of Electromagnetic Waves	L1, L2	Remember, Learn
	CO2	Apply the mathematical methods in solving Maxwell's equations	L3, L4	Apply, Analyse
	CO3	Analyze the wave propagation principles in different media	L4, L5	Analyse, Evaluate
	CO4	Evaluate the behavior of electromagnetic waves in different inhomogeneous media	L5, L6	Evaluate, Create
	CO5	Model Basic Electrodynamics using Simulation software	L5, L6	Evaluate, Create
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics PO1 PO2 PO3 PSO1 PSO2 PSO3			

		<table><tr><td>CO1</td><td>3</td><td>3</td><td>2</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO2</td><td>3</td><td>2</td><td>2</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO3</td><td>3</td><td>2</td><td>2</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO4</td><td>3</td><td>3</td><td>2</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO5</td><td>3</td><td>3</td><td>2</td><td>3</td><td>1</td><td>2</td></tr><tr><td colspan="7">1 - Slightly; 2 - Moderately; 3 - Substantially</td></tr></table>	CO1	3	3	2	3	1	2	CO2	3	2	2	3	1	2	CO3	3	2	2	3	1	2	CO4	3	3	2	3	1	2	CO5	3	3	2	3	1	2	1 - Slightly; 2 - Moderately; 3 - Substantially							
CO1	3	3	2	3	1	2																																							
CO2	3	2	2	3	1	2																																							
CO3	3	2	2	3	1	2																																							
CO4	3	3	2	3	1	2																																							
CO5	3	3	2	3	1	2																																							
1 - Slightly; 2 - Moderately; 3 - Substantially																																													
Syllabus Details:				Text/Ref. Books	Hrs	CO(s)																																							
Unit 1	Maxwell's Equations: Review of basic electromagnetic principles, deduction of Maxwell's equations, differential, integral and cylindrical coordinate form, boundary conditions.				9	CO1																																							
Unit 2	Electromagnetic waves: propagation of plane electromagnetic wave in free space, wave equation for conducting medium, conductors and dielectrics, polarization, directional cosines, reflection and refraction of plane waves, reflection at normal and oblique incidence, Fresnel's equations, polarization by reflection, total internal reflection.				9	CO1																																							
Unit 3	Pointing Vector: Pointing Theorem and Power Flow, Power Loss in a Plane Conductor.				6	CO1 CO2																																							
Unit 4	Wave guides: Parallel plane wave guides, TE, TM waves, transmission properties of TE, TM waves, voltage, current and power relations, rectangular wave guide, TE, TM waves, TE, TM waves in circular wave guides, attenuation factor and Q of wave guide, Propagation in wave guides with dielectric medium, dielectric slab wave guide.				9	CO1 CO2																																							
Unit 5	Inhomogeneous wave equation: Inhomogeneous wave equation it's solution. Lineard-Wiechert potentials. Field of a uniformly moving charge. Fields of an accelerated charge, Radiation from a charge at low velocity. Radiation from a charge at linear motion and circular motion or orbit. Bremsstrahlung- Cerenkov radiation				9	CO3, CO4																																							
Text Books (Must Know), Ref.		1. Griffiths, D.J., Introduction to Electrodynamics, Dorling Kingsle (1998).																																											

as (T-x) in the Syllabus	2. Puri, S.P., Classical Electrodynamics, Tata McGraw Hill, (1999).
Reference Book (Should Know) Ref. as (R-x) in the Syllabus	3. Jackson, J.D., Classical Electrodynamics, Wiley Eastern, (1999). 4. Jordan, E.C. and Balmain, K.G., Electromagnetic Wave and radiating systems, Prentice Hall of India, (2007).

CORE Courses-Semester I	
Subject Code	AP 503
Subject Title	Laser Technology
Credit	03
Teaching Scheme	Lectures: 03 hours/week
Evaluation Pattern	7. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 8. One Final Evaluation at the End of the Term 50 Marks 9. Assignments/Seminars: 10 Marks
Total Marks	100 Marks
Pre-requisite	Basic Physics Knowledge
About the Course	This course provides an in-depth understanding of the fundamental principles and technologies involved in lasers. This course provides a comprehensive introduction to the fundamental principles and operation of lasers. It covers the physical concepts underlying laser action, including stimulated emission, population inversion, and optical feedback. The course also explores the various types of lasers, their design, characteristics.
Course Objectives	• Explain the physical principles of laser operation, including the quantum mechanics of light-matter interaction. • Understand the role of gain media, pumping mechanisms, and optical resonators in laser systems. • Analyze the behavior of laser beams, including coherence, mode structure, and beam propagation.

	• Compare different types of lasers (gas, solid-state, semiconductor, fiber laser and amplifiers) and their applications. • Solve quantitative problems involving laser parameters such as output power, threshold conditions, and efficiency.								
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create								
CO Title			Bloom's Level and Descriptor						
	CO1:	Understand and explain the fundamental principles of laser physics, including stimulated emission, population inversion, and optical amplification.	Understand (Level 2)						
	CO2:	Analyze the operation of laser systems using rate equations and energy-level diagrams for different types of gain media	Apply (Level 3)						
	CO3:	Describe the components and function of optical resonators, and evaluate their role in mode selection and laser beam formation.	Analyze (Level 4)						
	CO4:	Apply concepts of Gaussian beam optics to describe laser beam propagation, focusing, divergence, and spot size.	Apply (Level 3)						
	CO5:	Solve quantitative problems related to laser threshold conditions, gain, power output, and efficiency.	Evaluate (Level 5)						
	CO6:	Create a laser system and perform basic laser experiments, including alignment, power measurement, and beam profiling, with proper safety precautions.	Apply (Level 6)						
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics								
		PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
	CO1	3	2	1			3	1	2
	CO2	2	3	1			3	1	2
	CO3	3	2	1			3	1	2
	CO4	3	2	1	1	1	3	1	2
	CO5	1	2	3	1	1	3	1	2
	CO6	1	1	1	1	3	3	1	2
Syllabus Details:					Text/Ref . Books	Hrs	CO(s)		
Unit 1	Light-matter interaction: Interaction of radiation with atomic systems. Einstein's				T1, T2	6	1		

	coefficients, spontaneous emission, stimulated emission, Linewidth of the laser, line broadening, concepts of Q-switching and modelocking			
Unit 2	Lasers Oscillation: Threshold condition, Rate equation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output, Spectral distribution, Spatial distribution and polarisation, Hole burning, Properties of laser beam, Pumping techniques.	T1, T2	12	2
Unit 3	Laser Resonators and Gaussian Beams: The Ray Matrix, Resonator Stability, Paraxial Wave Equation, Gaussian Beams, ABCD Law for Gaussian Beams, Gaussian Beam Modes, Hermite–Gaussian and Laguerre–Gaussian Beams, Resonators for He–Ne Lasers, Diffraction, Diffraction Theory of Resonators, Beam Quality, Resonators for High-Power Lasers.	T2, T3	10	3
Unit 4	Laser Systems 1: Neodymium-Based Lasers, Titanium Sapphire Laser, He–Ne Laser, CO₂ and Fiber Lasers & Amplifiers. Hands-On Experiments: Design Nd: YAG Laser, Fiber Laser & Amplifier (Students will design and assemble in a group)	T1, T2, T3	9	4
Unit 5	Laser Systems 2: Semiconductor Lasers, Optical Gain in Semiconductors, Quantum Well Lasers, Quantum Dot Laser, and Quantum Cascade Laser	T4	9	5
Text Books (Must Know), Ref. as (T-x) in the Syllabus	5. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007) 6. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998. 7. P. W. Milonni and J. H. Eberly, Lasers, Wiley Inter Science, 1988. 8. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).			
Reference Book (Should Know) Ref. as (R-x) in the Syllabus	4. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021). 5. Streetman, Ben, and Sanjay Banerjee. Solid state electronic devices. Pearson Higher Ed, 2015. 6. The W. Koechner, “Laser Fundamentals”			

Lab Course-Semester I		
Subject Code	AP 504L	
Subject Title	Optics and Photonics Lab	
Credit	03	
Teaching Scheme	Lectures: 06 hours/week	
Evaluation Pattern	1. Continuous Evaluations: Experiments, Lab Records and Vive-voce 40 Marks (20 + 10 + 10) 2. Mini-Project and Term Work Evaluations: 10 Marks 1. One Final Evaluation at the End of the Term 50 Marks	
Total Marks	100 Marks	
Pre-requisite	Laser safety tutorials/video demonstration of Laser safety followed by written test	
About the Course	The Optics & Photonics Laboratory course provides hands-on experience with the principles and applications of lasers, optical components, and electro-optic devices. It is designed to complement theoretical knowledge in optics and photonics with practical laboratory skills, emphasizing experimental methods, measurement techniques, and data analysis. This lab-centric course bridges the gap between classroom learning and real-world photonics applications, allowing students to explore the behaviour of light and optical systems through direct experimentation.	
Course Objectives	1. Understand the Principles of Optics and Optical sources such as Laser Operation 2. Gain Proficiency in Optical Alignment and Measurement 3. Operate and characterize various optical properties 4. Measure and Interpret Optical Phenomena 5. Develop Laboratory and Analytical Skills	
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create	
CO Title	Bloom's Level and Descriptor	
	CO1:	To make students familiar with advanced experiments in the field of lasers and electro-optics Understand (Level 2)
	CO2:	To make students realize usage of complex optical components and system design Analyze (Level 4)
	CO3:	To make students learn about real-time applications in optical communication Apply (Level 3)
	CO4:	To make students realize systematic data and report presentation in scientific methods Apply, Analyze (Level 3, Level4)
	CO5:	To analyze results obtained and verify with theory values and provide meaningful conclusion Evaluate (Level 5)

Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics									
		PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
	CO1	1	2				3	3	1	2
	CO2	1	3	2			3	3	1	2
	CO3	1	2	2	1	2	3	3	1	2
	CO4	1	3	3	1	3	2	3	1	2
	CO5	1	2	2	1	2	3	3	1	2
Syllabus Details:							Text/Ref. Books	Hrs	CO(s)	
List of Experiments:										
1.	Measurement of Refractive Index Using Michelson Interferometer						6	CO1		
2.	Measurement of the diameter of a thin wire using the laser light diffraction method.						6	CO1		
3.	Electrical and optical characteristics of optical sources (LEDs and Lasers)						6	CO3		
4.	Dispersive power of a prism using different light sources.						6	CO2		
5.	Beam collimation with different telescopic arrangements.						6	CO2		
6.	Finding the Verdict constant by the Faraday Effect						6	CO2		
7.	Determination of polarization states using polarizers, quarter waveplates, and half waveplates.						6	CO2		
8.	Spatial Filtering Experiment						6	CO2		
9.	Determination of Numerical Aperture and V-number of single-mode & multimode fiber.						6	CO3		
10.	Micro and Macro Bending losses in single-mode and multimode fiber and its application in sensing.						6	CO3		
11.	Determine the lines per inch of a Transmission diffraction grating by its dispersive angles.						6	CO3		
12.	Optisystem training module for Optical system designing						6	CO4		
13.	Young’s Single -slit and Double Slit Experiment						6	CO1- CO5		
Text Books (Must Know), Ref. as		1. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press,1989. References 2. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006. 3. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008								

(Tx) in the Syllabus	4. G. P. Agarwal, Fiber Optic Communication Systems, John Wiley & Sons, 2002. 5. Optical Fiber Communications – John M. Senior, PHI, 2nd Edition, 2002
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	1. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007) 2. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000. 3. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998.

SEMESTER – II

CORE Courses-Semester II	
Subject Code	AP 505
Subject Title	Solid State Physics
Credit	04
Teaching Scheme	Lectures: 03 hours/week + Tutorial
Evaluation Pattern	7. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 8. One Final Evaluation at the End of the Term 50 Marks 9. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks
Total Marks	100 Marks
Pre-requisite	B.Sc. Physics or Engineering Physics Knowledge
About the Course	1] Understand the structure of solids: - Identify and describe different types of crystal structures. - Analyze unit cells, lattice types, and symmetry operations. - Interpret X-ray diffraction and its application in determining crystal structure. 3] Study lattice dynamics: - Understand vibrations in a crystal lattice and the concept of phonons. - Analyze the heat capacity of solids using classical and quantum models (Einstein and Debye models). 3] Analyze electronic properties of solids and band structure: - Understand free electron and nearly free electron models. - Learn about energy bands, Brillouin zones, and band structure. - Distinguish between conductors, semiconductors, and insulators. 4] Study Dielectric and Magnetic properties of Solids - Learn about Macroscopic and local electric field in solids

	• Understand Polarizability and Dielectric constant • Understand magnetism • Analyze nature of different types of magnetism						
Course Objectives	This course is necessary for students to understand structure property relationships in Physics. Also this course is a first step towards understanding Condensed Matter Physics.						
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create						
CO Title				Level	Descriptor		
	CO1:	Understand the structure of solids		1, 2	Remember; Understand		
	CO2:	Study lattice dynamics		2, 3	Understand; Apply		
	CO3:	Analyze electronic properties of solids and band structure		2, 3	Understand; Apply		
	CO4:	Study Dielectric and Magnetic properties of Solids		3, 4	Apply; Analyze		
	CO5:	Illustrate the correlation between structure and physical properties of solids		3, 4, 5	Apply; Analyze; Evaluate;		
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics						
		PO1	PO2	PO3	PSO1	PSO2	PSO3
	CO1	3	2	1	3	1	2
	CO2	3	1	2	3	1	2
	CO3	1	2	3	3	1	2
	CO4	1	3	2	3	1	2
	CO5	1	2	3	3	1	2
Syllabus Details:				Text/Ref. Books	Hrs	CO(s)	
Unit 1	Crystal Structure and Diffraction: Real lattices, packing fraction, reciprocal lattices, Brillouin zones. Diffraction by crystals - Ewald sphere construction, Bragg condition in k-space. Geometric structure factor and atomic form factor. Point defects, line defects and islocations			T1, T3, R4	9	1	
Unit 2	Lattice Dynamics: Vibrations of crystals with mono-atomic and diatomic basis. Brillouin zones. Optical			T1, T3, R5	9	2	

	modes and acoustic modes. Quantization of elastic waves. Phonon momentum. Neutron scattering by phonons. Phonon heat capacity. Phonon density of states. Einstein and Debye theories , thermal conductivity.			
Unit 3	Electronic Band Structure in Crystals: Drude theory of metals. Quantum free electron model of metals (Sommerfeld model). Nearly free electron theory. Brillouin zones. Electron effective mass. Density of states and band gap. Kronig-Penney model. Bloch theorem. Crystal momentum. Qualitative distinction between semiconductors and metals. Fermi surface of metals. Hall effect.	T1, T2, R5	9	3
Unit 4	Dielectric and Magnetic Properties of Solids: Macroscopic electric field and local electric field in solids. Polarizability and dielectric constant. Claussius-Mossotti relation. Dielectric-Ferroelectric phase transition. Landau theory. Piezoelectricity.	T-2, T-3	9	4
Unit 5	Diamagnetism – Langevin equation. Pauli paramagnetism in metals. Paramagnetism –Curie law. Ferromagnetism. Quantum mechanical nature of ferromagnetic interaction. Anti-ferromagnetic and ferromagnetic order.	T-1, T-2, R-4	9	5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. Solid State Physics, N. W. Ashcroft and N. D. Mermin (CBS Publishing Asia Ltd.). 2. Introduction to Solid State Physics, Charles Kittel (John Wiley and Sons.).			
Reference Book	1. Solid State Physics, A. J. Dekkar (Prentice Hall).			

(Should Know) Ref. as (Rx) in the Syllabus	

Lab Course-Semester II		
Subject Code	AP 506L	
Subject Title	Photonics and Electronics Lab	
Credit	03	
Teaching Scheme	Lectures: 06 hours/week	
Evaluation Pattern	3. Continuous Evaluations: Experiments, Lab Records and Vive-voce 40 Marks (20 + 10 + 10) 4. Mini-Project and Term Work Evaluations: 10 Marks 2. One Final Evaluation at the End of the Term 50 Marks	
Total Marks	100 Marks	
Pre-requisite	Laser safety tutorials/video demonstration of Laser safety followed by written test	
About the Course	The Photonics and Electronics Laboratory course provides hands-on experience with the principles and applications of lasers, optical components, and electro-optic devices. It is designed to complement theoretical knowledge in optics and photonics with practical laboratory skills, emphasizing experimental methods, measurement techniques, and data analysis. This lab-centric course bridges the gap between classroom learning and real-world photonics applications, allowing students to explore the behaviour of light and optical systems through direct experimentation.	
Course Objectives	1. Understand the Principles of optical instrumentation 2. To conduct basic electronic experiments 3. Measure and Interpret Optical Phenomena 4. Develop Laboratory and Analytical Skills 5. To inculcate the habit of scientific writing among the students	
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create	
CO Title	Bloom's Level and Descriptor	
	CO1:	To make students familiar with advanced experiments in the field of lasers and electro-optics Understand (Level 2)
	CO2:	To make students realize usage of complex optical components and system design Analyze (Level 4)
	CO3:	To make students learn about real-time applications in optical communication Apply (Level 3)

	CO4:	To make students realize systematic data and report presentation in scientific methods					Apply, Analyze (Level 3, Level4)			
	CO5:	To analyze results obtained and verify with theory values and provide meaningful conclusion					Evaluate (Level 5)			
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics									
		PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
	CO1	1	2				3	3	1	2
	CO2	1	3	2			3	3	1	2
	CO3	1	2	2	1	2	3	3	1	2
	CO4	1	3	3	1	3	2	3	1	2
	CO5	1	2	2	1	2	3	3	1	2
Syllabus Details:							Text/Ref. Books	Hrs	CO(s)	
	<u>List of Experiments:</u>									
	1	Beam Width Divergence of He-Ne/Diode Laser.							6	CO1
	2.	Fiber optic link design							6	CO1
	3.	Measurement of attenuation and Dispersion in optical Fibers							6	CO3
	4.	Fiber Splicing							6	CO2
	5.	Setting up of Mach-Zehnder Interferometer							6	CO2
	6.	Characterization of Erbium-doped fiber amplifier							6	CO2
	7.	Holography							6	CO2
	8.	To study the VI characteristics of Diodes (simple and Zener Diode)							6	CO2
	9.	To study the VI Characteristics of Transistors in CB, CE, CC modes (NPN & PNP Transistors)							6	CO3
	10.	To study the VI Characteristics of MOSFETs							6	CO3
	11.	To Study the Half, Full and Bridge rectifier							6	CO3
	12.	To study the Voltage and Current regulation with a fixed load							6	CO4
	13.	To study the clipping and clamping circuit							6	CO1-CO5
	14.	To study the Characteristics of 741 OPAMPS							6	CO2
	15.	To analyze the inverting and non-inverting amplifier							6	CO2

Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press, 1989. References 2. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006. 3. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008 4. G. P. Agarwal, Fiber Optic Communication Systems, John Wiley & Sons, 2002. 5. Optical Fiber Communications – John M. Senior, PHI, 2nd Edition, 2002
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	1. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007) 2. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000. 3. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998.

SEMESTER – III

CORE Courses-Semester I	
Subject Code	AP 508
Subject Title	Semiconductor Optoelectronic Devices
Credit	04
Teaching Scheme	Lectures: 03 hours/week + 1 hr tutorial/ practical
Evaluation Pattern	10. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 11. One Final Evaluation at the End of the Term 50 Marks 12. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks
Total Marks	100 Marks
Pre-requisite	B.Sc. Physics or Engineering Physics Knowledge
About the Course	Semiconductor Photonic Devices is the basic to advanced level subject which provides fundamental knowledge of different semiconductor material and its application in the photonic devices from sources to detectors. The course will give a explanation about working principles of devices such as LEDs, lasers, Detector, Photonic integrated circuit etc. The course will start with the introduction to properties of semiconductors, band structures, optical electronics, solving of Maxwell's equations, wave equation in anisotropic media, Uniaxial and biaxial crystals, the determination of dielectric constant, tensor

	and the ‘index ellipsoid’. The Fresnel’s equation also explored for Reflection and Refraction of plane waves. Later, it also covers the concepts of polarization of light through different optical components, like Polarizers, Quarter, Half, and Full waveplates, Beam splitters, wavelength filters, dichroic mirrors, Lenses, etc. It also deals with study of absorption and dispersion, Jones Calculus, Poincare sphere, with polarized and non-polarized lights. In unit 3, Electro-optical effects such as, Pockel and Kerr effects, Electro-optic modulators, switches, and scanners, E.O. effect in liquid crystals are discussed thoroughly and their applications in LCDs and SLMs. Furthermore, the Acousto-optical effects, like, Strain waves in solids and liquids, the strain-optic tensor, theory of Raman-Nath and Bragg diffraction, small-angle and large-angle Bragg diffraction are explained with derivation. Acousto-optic devices, such as, modulators, deflectors, scanners, interconnections, acousto-optic tunable filters, are studied thoroughly. Similarly, in Unit 5, the Magneto-optical effects, such as, Faraday effect, Gyrotropic permittivity, Kerr rotation, and Kerr ellipticity and its applications also been discussed. Finally, the current status of development and applications of this areas are covered.		
Course Objectives	This course is helping M. Tech. ‘Laser and Electro-optics’ students and similar branches to understand how the opto-electronic systems are working to fulfil the current needs of our society.		
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create		
CO Title		Level	Descriptor
	CO1: Understand the basics of Semiconductor Physics	1, 2	Remember; Understand
	CO2: Interpret all the optical properties and processes in semiconductors	2, 3	Understand; Apply
	CO3: Examine the working mechanism of different kinds of LEDs and LASERS	2, 3	Understand; Apply
	CO4: Illustrate the implementation of Modulation and Switching Devices	3, 4	Apply; Analyze
	CO5: Explain different types of photodiodes and photodetectors	3, 4, 5	Apply; Analyze; Evaluate;

Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics						
		PO1	PO2	PO3	PSO1	PSO2	PSO3
	CO1	3	2	1	3	1	2
	CO2	3	1	2	3	1	2
	CO3	1	2	3	3	1	2
	CO4	1	3	2	3	1	2
	CO5	1	2	3	3	1	2
Syllabus Details:					Text/Ref. Books	Hrs	CO(s)
Unit 1	Review of Semiconductor Physics: Atoms, Molecules and Solids, Energy Bands, Density of States, Fermi-level, PN Junction, Homo and Hetero Junction, Quantum Wells. Semiconductor Optoelectronic materials, ~~Electron-hole pairs~~ , Interaction of Photons with Electrons and Holes				T1, T3, R4	9	1
Unit 2	Light Emitting Diodes: The electroluminescence Process, LED materials, Device configuration and Efficiency, LED structures, LED performance characteristics, Frequency response and Modulation bandwidth. LEDs for display and Lighting.				T1, T3, R5	9	2
Unit 3	Semiconductor Lasers: Junction Laser Operating Principles, Threshold Current, Heterojunction Laser, Distributed Feedback Lasers and Distributed Bragg Reflector, Ring Lasers: Single and Double, Master Oscillator Power Amplifier. VCSELS and Laser Diode Arrays. , Laser Modulation Bandwidth.				T1, T2, R5	12	3
Unit 4	Modulation and Switching Devices: Analog and Digital Modulation of light sources, Franz-Keldysh and Stark-effect based Modulators, QW Electro-absorption modulator.				T-2, T-3	6	4
Unit 5	Photodetectors: Types of photodetectors, Photoconductors, Junction photodiode, PIN photodiode and APD, Noise in Photodetectors, Quantum Well IR Detectors, High Speed Measurements, Detectors for long wavelength operation, Wavelength selective detection, CCDs and PICs.				T-1, T-2, R-4	9	5
Text Books (Must Know), Ref. as (Tx) in the Syllabus		4. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995). 5. G. Ghione, Semiconductor Devices for High-Speed Optoelectronics, Cambridge University Press (2009) 6. A. Yariv and P. Yeh, Photonics: Optical Electronics in Modern Communication, Oxford University Press (2007), 6 th Ed., Ch.15-17.					

Reference Book (Should Know) Ref. as (Rx) in the Syllabus	5. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007), Ch.16, 17. 6. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021). 7. Streetman, Ben, and Sanjay Banerjee. Solid state electronic devices. Pearson Higher Ed, 2015.

Note: A few core/elective courses are common courses across the other programs, and details can be found at the respective programs.

M.Sc. Tech. (Photonics)

M. Sc. Tech (Photonics)

One of the greatest scientific discoveries of the twentieth century that has led to technological advancement touching all aspects of human life is the LASER. Applications of lasers range from medical applications, communications, and industrial applications to military applications. An understanding of laser technology is essential for an engineer working in many of the present-day cutting-edge technologies. The aim of this program is to train the students in the field of lasers, fiber optics, electro-optics, and photonics that would enable them to meet the challenges in this rapidly developing field.

Stakeholders:

- (i) Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments
- (ii) Graduates in the relevant field of science/technology from recognized Universities across the country.

Eligibility for Students:

The candidate should possess Bachelor's degree or equivalent in Physics, Applied Physics, Engineering Physics, Electronic Science, Photonics, Optics, Material Science, Instrumentation Science or any equivalent branch

OR

B. Tech. (Any discipline)

Organization: The M. Sc. Tech. Programme is of six-semester duration. In each of the first three semesters there are six theory courses and one laboratory course. The fourth semester is having one mini-project along with four theory courses and one laboratory course. There will be three continuous evaluation examinations and a final semester examination for every course. Half yearly evaluation of the final year project takes place at the end of the fifth semester. At the end of the final semester, the student submits a dissertation and makes a presentation about the work carried out by him/her on the project, which is evaluated by the Internal and External examiners. Course syllabus is updated periodically to keep pace with the contemporary technological advancement.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO1: The M. Sc. Tech. in Photonics Programme aims at developing skilled human resources in the field of Optics, lasers, Electro-optics and overall Photonics. It will ensure the understanding of applied optics, physics and engineering laser technology, fiber optics, semiconductor photonic devices, laser systems and its various applications, catering to the emerging multidisciplinary problems faced by defence industry and civilization.

- PO1 Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- PO2 Problem Analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.
- PO3 Design/Development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- PO4 Conduct Investigations of Complex Problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions for complex problems.
- PO5 Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and Modeling to complex engineering activities with an understanding of the limitations.
- PO6 The Engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PEO2: With a focus on the DRDO requirements, the students will be trained to use their knowledge for the benefit of society and made aware of their social duty. This will enable them to pursue career in research, academics and industry.

PEO3: At the end of the Programme the officer or student should be able to undertake state of the art R&D in lasers and electro-optic systems and competitively work towards development of the latest technology in line with national Programmes like Make in India.

P

PROGRAMME OUTCOMES (POs)

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Sc. Tech. (Photonics) Programme, graduates will be able to

PSO1: The M. Sc. Tech. in Photonics aims at developing a skilled knowledgeable Human task force in the field of Photonics serving the needs of the Defence Research and Development Organization & Tri – services (Army, Navy & Air force), Coast Guard, DGQA, DQA, Defence Public Sector units, in addition to the civilians in general. After completing the course, the students develop an ability to carry out independent research in the area of optical devices.

PSO2: The dissertation work of the M. Sc. Tech. students leads to publications in high impact international journals which trains them in technical documentation and report writing.

PSO3: The goal of the M. Sc. Tech. in Photonics course is to generate highly competent human resources in the areas of laser development, electro-optic systems, fibre optics, applied optics, and computational photonics.

M.Sc. Tech. (Photonics) Program Structure:

PSC: Program Specific Core PSL: Program Specific Lab PE: Professional Elective

SEMESTER I

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-1	AP 501	Quantum Mechanics	3	1	4
2	PSC-2	AP 502	Electromagnetic wave Theory	3	1	4
3	PSC-3	AP 503	Fundamentals of Lasers	3	0	3
4	PSC-4	AP 614	Optical Electronics	3	0	3
5	PSL	AP 504L	Photonics Lab	0	4	2
6	PGC	RM-501	Research Methodology	2	0	4
			Total			20

SEMESTER II

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-5	AP 505	Solid State Physics	3	1	4
2	PSC-6	AP 621	Fiber Optic devices and systems	3	1	4
3	PE-I	AP XXX	Elective 1	3	0	3
4	PE-II	AP XXX	Elective 2	3	0	3
5	PSL/PSC/PE	AP 506L	Photonics and Electronics Lab	0	4	2
6	OJT/FP	AP 507 - OJT	On Job Training/Field Project (120 Hrs)	0	0	4
			Total			20

SEMESTER III

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-7	AP 508	Semiconductor Optoelectronic Devices	3	1	4
2	PSC-8	EE 620	System on Chip and Embedded Systems	3	0	3
3	PE - III	AP XXX		3	0	3
4	PE - IV	AP XXX		3	0	3
5	PE - V	AP XXX		0	0	3
6	PSL	AP509L	Advanced Photonics Lab		8	4
			Total			20

SEMESTER IV

Sl. No.	Course Type	Course Code	Course	Contact Hours/week		Credits
				L	T/P	
1	PSC-9	AP 616	Laser Applications	3	1	3
2	PSC-10	AP 619	TeraHertz Devices and Applications	3	0	3
3	PE - III	AP XXX		3	0	3
4	PE - IV	AP XXX		3	0	3
5	PGC	PGC 602	Personality Development	0	0	2
6	PSL	AP 550	Research project		12	6
			Total			20

SEMESTER V

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP 551	Dissertation Phase - I			20
		Total			20

Sr. No.	Course Code	Course
1.	AP 602	Technology & Packaging of MEMS
2	Open Elective/ MOOC Course (The course names are only indicative to guide the student. Students have the choice to take a course other than those listed, as per department guidance.	9. Introduction to Nanoscience and Nanotechnology 10. Data Science 11. Indian Knowledge System 12. Cyber Security
	The electives and other Core Courses offered in the 2 nd semester by the other departments may be opted by the students on consultation with the course OIC/Department.	
	A maximum of 6 Credits can be opted by students as Professional Electives from the list of Online Courses on NPTEL/SWAYAM, which are aligned with the program may be opted by the students on consultation with the course OIC/Department.	

SEMESTER VI

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP 552	Dissertation Phase-II			20
		Total			20

List of Subjects (Applicable for Sem - II):

Sr.No.	Course Code	Course
1.	AP 620	Nanophotonics
2.		High Power Fiber lasers
3.	Open Elective/ MOOC Course (The course names are only indicative to guide the student. Students have the choice to take a course other than those listed, as per department guidance)	8. RF Photonics 9. Nonlinear Optics 10. Applied Optics 11. Bio photonics 12. Python programming

List of Electives/Open Electives (Applicable for Sem - III):

List of Electives/Open Electives (Applicable for Sem – IV)

Sr.No.	Course Code	Course
1	AP604	Sensor Systems
2	Open Elective/ MOOC Course (The course names are only indicative to guide the student. Students have the choice to take a course other than those listed, as per department guidance)	1. Quantum Optics 2. Optical Space Communications 3. Machine Learning 4. Quantum Communication

SEMESTER – I

CORE Courses-Semester I			
Subject Code	AP 501		
Subject Title	Quantum Mechanics		
Credit	04		
Teaching Scheme	Lectures: 03 hours/week + 1 hour tutorial		
Evaluation Pattern	7. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 8. One Final Evaluation at the End of the Term 50 Marks 9. Assignments & Term Work Evaluations: 10 Marks		
Total Marks	100 Marks		
Pre-requisite	None		
About the Course	This course provides a foundational understanding of Quantum Mechanics, essential for students in physics and engineering disciplines working with atomic, molecular, and photonic systems. It introduces the mathematical formalism of quantum theory and its physical interpretations, enabling students to analyze simple quantum systems such as potential wells, harmonic oscillators, and one-electron atoms. Additionally, it covers quantum statistics and forms the basis for understanding lasers and modern quantum technologies		
Course Objectives	By the end of this course, the students will be able to: • Understand the fundamental postulates of quantum mechanics and how they differ from classical physics. • Formulate and solve the Schrödinger equation for various potential problems in one and three dimensions. • Apply the formalism of quantum mechanics, including Hilbert spaces, operators, and Dirac notation. • Analyze atomic systems, such as the hydrogen atom, using appropriate mathematical tools. • Explore the principles of quantum statistics and their role in physical systems involving indistinguishable particles. • Relate quantum mechanical principles to practical systems such as lasers, optical devices, and semiconductor physics.		
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create		
CO Title			Level
			Descriptor
	CO1:	Explain core concepts of thermal radiation, Planck's postulates, and Schrödinger's equation.	2
	CO2:	Solve quantum systems such as potential wells and harmonic oscillators using	3
			Understand
			Apply

		analytical techniques.							
	CO3:	Apply Dirac notation, operator algebra, and statistical interpretation in solving quantum mechanical problems.	4, 5	Apply/Analyze					
	CO4:	Analyze hydrogen-like atoms and interpret eigenvalue problems in three-dimensional quantum systems.	4	Analyze					
	CO5:	Explain and apply the principles of quantum statistics and their applications in quantum devices.	2, 3	Understand/Apply0020					
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics								
		PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
	CO1	3	2	-	1		3	1	2
	CO2	3	3	2	2		3	1	2
	CO3	3	3	-	2		3	1	2
	CO4	3	3	-	2		3	1	2
	CO5	3	2	-	2	1	3	1	2
Syllabus Details:									
Unit 1	Introduction: Thermal radiation, Plank's postulates, The Schrödinger equation, Statistical interpretation, probability, normalization, momentum, the uncertainty principle			Text Book-1, Ch- 1 Text Book 2 Chapter 1		10 Hrs		CO1	
Unit 2	Time Independent Schrödinger: stationary states, infinite square well, harmonic oscillator, free particle, delta function potential, finite square well			Text Book-2 Chapter 2		9 Hrs		CO2	
Unit 3	Formalism: Hilbert's space, observables, eigen function of Hermitian operator, statistical interpretation, Dirac notation			Book 1 Ch-2 Book 2 Ch-3		9 Hrs		CO3	
Unit 4	One electron atoms: solution of Schrödinger equation in 3D, eigen values, quantum numbers, and degeneracy, orbital angular			Text Book 1 CH-4		9 Hrs		CO4	

Unit 5	Quantum statistics: indistinguishability and quantum statistics, quantum distribution functions, Boltzmann distribution as an approximation to quantum distributions, The Lasers	Text Book 1 Ch-8 Reference Book 1	8 Hrs	CO5
Unit 6	Quantum Mechanics in Modern Applications Introduction to Quantum Entanglement and Bell's Inequality Quantum Tunneling and its Applications (e.g., Tunnel Diode, STM) Basics of Quantum Computing: Qubits, Superposition, and Quantum Gates Quantum Cryptography and Quantum Teleportation (Introductory Concepts) Quantum Dots and Nano-scale Systems	Text Book 1 Reference Book 1	9 Hrs	CO5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. Zettili, Nouredine. "Quantum mechanics: concepts and applications." John Wiley and Sons, Ltd., Publishing 2nd Ed. (2009) 6. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing Limited			
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	5. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing 6. Beiser, Arthur. Concepts of modern physics. 2003.			

CORE Courses-Semester I								
Subject Code		AP 502						
Subject Title		Electromagnetic Wave Theory						
Credit		04						
Teaching Scheme		Lectures: 03 hours/week						
Evaluation Pattern		13. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 14. One Final Evaluation at the End of the Term 50 Marks 15. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks						
Total Marks		100 Marks						
Pre-requisite		Basic physics knowledge						
About the Course								
Course Objectives								
Course Outcomes		Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create						
CO Title								
		CO1	Understand the basic concepts of Electromagnetic Waves	L1, L2	Remember, Learn			
		CO2	Apply the mathematical methods in solving Maxwell's equations	L3, L4	Apply, Analyse			
		CO3	Analyze the wave propagation principles in different media	L4, L5	Analyse, Evaluate			
		CO4	Evaluate the behavior of electromagnetic waves in different inhomogeneous media	L5, L6	Evaluate, Create			
		CO5	Model Basic Electrodynamics using Simulation software	L5, L6	Evaluate, Create			
Summary of the Course Outcome		Course Outcome and Program Outcome Evaluation Metrics						
			PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1		3	3	2	3	1	2	
CO2		3	2	2	3	1	2	
CO3		3	2	2	3	1	2	
CO4		3	3	2	3	1	2	
CO5		3	3	2	3	1	2	
		1 - Slightly; 2 - Moderately; 3 - Substantially						
Syllabus Details:					Text/Ref. Books	Hrs	CO(s)	
Unit 1	Maxwell's Equations: Review of basic electromagnetic principles, deduction of Maxwell's equations, differential, integral and cylindrical coordinate form, boundary conditions.					9	CO1	

Unit 2	Electromagnetic waves: propagation of plane electromagnetic wave in free space, wave equation for conducting medium, conductors and dielectrics, polarization, directional cosines, reflection and refraction of plane waves, reflection at normal and oblique incidence, Fresnel's equations, polarization by reflection, total internal reflection.		9	CO1
Unit 3	Pointing Vector: Pointing Theorem and Power Flow, Power Loss in a Plane Conductor.		6	CO1 CO2
Unit 4	Wave guides: Parallel plane wave guides, TE, TM waves, transmission properties of TE, TM waves, voltage, current and power relations, rectangular wave guide, TE, TM waves, TE, TM waves in circular wave guides, attenuation factor and Q of wave guide, Propagation in wave guides with dielectric medium, dielectric slab wave guide.		9	CO1 CO2
Unit 5	Inhomogeneous wave equation: Inhomogeneous wave equation it's solution. Lineard-Wiechert potentials. Field of a uniformly moving charge. Fields of an accelerated charge, Radiation from a charge at low velocity. Radiation from a charge at linear motion and circular motion or orbit. Bremsstrahlung- Cerenkov radiation		9	CO3, CO4
Text Books (Must Know), Ref. as (T-x) in the Syllabus	3. Griffiths, D.J., Introduction to Electrodynamics, Dorling Kingsley, (1998). 4. Puri, S.P., Classical Electrodynamics, Tata McGraw Hill, (1999).			
Reference Book (Should Know) Ref. as (R-x) in the Syllabus	8. Jackson, J.D., Classical Electrodynamics, Wiley Eastern, (1999). 9. Jordan, E.C. and Balmain, K.G., Electromagnetic Wave and radiating systems, Prentice Hall of India, (2007).			

CORE Courses-Semester I		
Subject Code	AP 503	
Subject Title	Laser Technology	
Credit	03	
Teaching Scheme	Lectures: 03 hours/week	
Evaluation Pattern	10. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 11. One Final Evaluation at the End of the Term 50 Marks 12. Assignments/Seminars: 10 Marks	
Total Marks	100 Marks	
Pre-requisite	Basic Physics Knowledge	
About the Course	This course provides an in-depth understanding of the fundamental principles and technologies involved in lasers. This course provides a comprehensive introduction to the fundamental principles and operation of lasers. It covers the physical concepts underlying laser action, including stimulated emission, population inversion, and optical feedback. The course also explores the various types of lasers, their design, characteristics.	
Course Objectives	• Explain the physical principles of laser operation, including the quantum mechanics of light-matter interaction. • Understand the role of gain media, pumping mechanisms, and optical resonators in laser systems. • Analyze the behavior of laser beams, including coherence, mode structure, and beam propagation. • Compare different types of lasers (gas, solid-state, semiconductor, fiber laser and amplifiers) and their applications. • Solve quantitative problems involving laser parameters such as output power, threshold conditions, and efficiency.	
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create	
CO Title	Bloom's Level and Descriptor	
	CO1:	Understand and explain the fundamental principles of laser physics, including stimulated emission, population inversion, and optical amplification.
	CO2:	Analyze the operation of laser systems using rate equations and energy-level diagrams for different types of gain media
	CO3:	Describe the components and function of optical resonators, and evaluate their

		role in mode selection and laser beam formation.							
	CO4:	Apply concepts of Gaussian beam optics to describe laser beam propagation, focusing, divergence, and spot size.	Apply (Level 3)						
	CO5:	Solve quantitative problems related to laser threshold conditions, gain, power output, and efficiency.	Evaluate (Level 5)						
	CO6:	Create a laser system and perform basic laser experiments, including alignment, power measurement, and beam profiling, with proper safety precautions.	Apply (Level 6)						
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics								
		PO1	PO2	PO3	PO4	PO5	PSO1	PSO2	PSO3
	CO1	3	2	1			3	1	2
	CO2	2	3	1			3	1	2
	CO3	3	2	1			3	1	2
	CO4	3	2	1	1	1	3	1	2
	CO5	1	2	3	1	1	3	1	2
	CO6	1	1	1	1	3	3	1	2
Syllabus Details:					Text/Ref. Books	Hrs	CO(s)		
Unit 1	Light-matter interaction: Interaction of radiation with atomic systems, Einstein’s coefficients, spontaneous emission, stimulated emission, Linewidth of the laser, line broadening, concepts of Q-switching and modelocking				T1, T2	6	1		
Unit 2	Lasers Oscillation: Threshold condition, Rate equation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output, Spectral distribution, Spatial distribution and polarisation, Hole burning, Properties of laser beam, Pumping techniques.				T1, T2	12	2		
Unit 3	Laser Resonators and Gaussian Beams: The Ray Matrix, Resonator Stability, Paraxial Wave Equation, Gaussian Beams, ABCD Law for Gaussian Beams, Gaussian Beam Modes, Hermite–Gaussian and Laguerre–Gaussian Beams, Resonators for He–Ne Lasers, Diffraction, Diffraction Theory of Resonators, Beam Quality, Resonators for High-Power Lasers.				T2, T3	10	3		
Unit 4	Laser Systems 1: Neodymium-Based Lasers, Titanium Sapphire Laser, He–Ne Laser, CO ₂ and Fiber Lasers & Amplifiers. Hands-On Experiments: Design Nd: YAG Laser, Fiber Laser & Amplifier (Students will design and assemble in a group)				T1, T2, T3	9	4		
Unit 5	Laser Systems 2: Semiconductor Lasers, Optical				T4	9	5		

	Gain in Semiconductors, Quantum Well Lasers, Quantum Dot Laser, and Quantum Cascade Laser			
Text Books (Must Know), Ref. as (T-x) in the Syllabus	9. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007) 10. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998. 11. P. W. Milonni and J. H. Eberly, Lasers, Wiley Inter Science, 1988. 12. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).			
Reference Book (Should Know) Ref. as (R-x) in the Syllabus	7. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021). 8. Streetman, Ben, and Sanjay Banerjee. Solid state electronic devices. Pearson Higher Ed, 2015. 9. The W. Koechner, "Laser Fundamentals"			

Lab Course-Semester I	
Subject Code	AP 504L
Subject Title	Optics and Photonics Lab
Credit	03
Teaching Scheme	Lectures: 06 hours/week
Evaluation Pattern	5. Continuous Evaluations: Experiments, Lab Records and Vive-voce 40 Marks (20 + 10 + 10) 6. Mini-Project and Term Work Evaluations: 10 Marks 3. One Final Evaluation at the End of the Term 50 Marks
Total Marks	100 Marks
Pre-requisite	Laser safety tutorials/video demonstration of Laser safety followed by written test
About the Course	The Optics & Photonics Laboratory course provides hands-on experience with the principles and applications of lasers, optical components, and electro-optic devices. It is designed to complement theoretical knowledge in optics and photonics with practical laboratory skills, emphasizing experimental methods, measurement techniques, and data analysis. This lab-centric course bridges the gap between classroom learning and real-world photonics applications, allowing students to explore the behaviour of light and optical systems through direct experimentation.
Course Objectives	6. Understand the Principles of Optics and Optical sources such as Laser Operation 7. Gain Proficiency in Optical Alignment and Measurement 8. Operate and characterize various optical properties 9. Measure and Interpret Optical Phenomena 10. Develop Laboratory and Analytical Skills
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5

		Evaluate; Level-6 Create								
CO Title								Bloom's Level and Descriptor		
	CO1:	To make students familiar with advanced experiments in the field of lasers and electro-optics							Understand (Level 2)	
	CO2:	To make students realize usage of complex optical components and system design							Analyze (Level 4)	
	CO3:	To make students learn about real-time applications in optical communication							Apply (Level 3)	
	CO4:	To make students realize systematic data and report presentation in scientific methods							Apply, Analyze (Level 3, Level4)	
	CO5:	To analyze results obtained and verify with theory values and provide meaningful conclusion							Evaluate (Level 5)	
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics									
		PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
	CO1	1	2				3	3	1	2
	CO2	1	3	2			3	3	1	2
	CO3	1	2	2	1	2	3	3	1	2
	CO4	1	3	3	1	3	2	3	1	2
	CO5	1	2	2	1	2	3	3	1	2
Syllabus Details:							Text/Ref. Books	Hrs	CO(s)	
	List of Experiments:									
14.	Measurement of Refractive Index Using Michelson Interferometer							6	CO1	
15.	Measurement of the diameter of a thin wire using the laser light diffraction method.							6	CO1	
16.	Electrical and optical characteristics of optical sources (LEDs and Lasers)							6	CO3	
17.	Dispersive power of a prism using different light sources.							6	CO2	
18.	Beam collimation with different telescopic arrangements.							6	CO2	
19.	Finding the Verdict constant by the Faraday Effect							6	CO2	
20.	Determination of polarization states using polarizers, quarter waveplates, and half waveplates.							6	CO2	
21.	Spatial Filtering Experiment							6	CO2	
22.	Determination of Numerical Aperture and V-number of single-mode & multimode fiber.							6	CO3	
23.	Micro and Macro Bending losses in single-mode and multimode fiber and its application in sensing.							6	CO3	

	24.	Determine the lines per inch of a Transmission diffraction grating by its dispersive angles.	6	CO3
	25.	Optisystem training module for Optical system designing	6	CO4
	26.	Young's Single -slit and Double Slit Experiment	6	CO1-CO5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	6. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press, 1989. References 7. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006. 8. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008 9. G. P. Agarwal, Fiber Optic Communication Systems, John Wiley & Sons, 2002. 10. Optical Fiber Communications – John M. Senior, PHI, 2nd Edition, 2002			
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	4. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007) 5. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000. 6. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998.			

SEMESTER – II

CORE Courses-Semester II	
Subject Code	AP 505
Subject Title	Solid State Physics
Credit	04
Teaching Scheme	Lectures: 03 hours/week + Tutorial
Evaluation Pattern	16. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 17. One Final Evaluation at the End of the Term 50 Marks 18. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks
Total Marks	100 Marks
Pre-requisite	B.Sc. Physics or Engineering Physics Knowledge
About the Course	1] Understand the structure of solids: - Identify and describe different types of crystal structures. - Analyze unit cells, lattice types, and symmetry operations. - Interpret X-ray diffraction and its application in determining crystal structure.

	3] Study lattice dynamics: - Understand vibrations in a crystal lattice and the concept of phonons. - Analyze the heat capacity of solids using classical and quantum models (Einstein and Debye models). 3] Analyze electronic properties of solids and band structure: - Understand free electron and nearly free electron models. - Learn about energy bands, Brillouin zones, and band structure. - Distinguish between conductors, semiconductors, and insulators. 4] Study Dielectric and Magnetic properties of Solids - Learn about Macroscopic and local electric field in solids - Understand Polarizability and Dielectric constant - Understand magnetism - Analyze nature of different types of magnetism						
Course Objectives	This course is necessary for students to understand structure property relationships in Physics. Also this course is a first step towards understanding Condensed Matter Physics.						
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create						
CO Title			Level	Descriptor			
	CO1:	Understand the structure of solids	1, 2	Remember; Understand			
	CO2:	Study lattice dynamics	2, 3	Understand; Apply			
	CO3:	Analyze electronic properties of solids and band structure	2, 3	Understand; Apply			
	CO4:	Study Dielectric and Magnetic properties of Solids	3, 4	Apply; Analyze			
	CO5:	Illustrate the correlation between structure and physical properties of solids	3, 4, 5	Apply; Analyze; Evaluate;			
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics						
		PO1	PO2	PO3	PSO1	PSO2	PSO3
	CO1	3	2	1	3	1	2
	CO2	3	1	2	3	1	2
	CO3	1	2	3	3	1	2
	CO4	1	3	2	3	1	2
	CO5	1	2	3	3	1	2
Syllabus Details:			Text/Ref. Books	Hrs	CO(s)		
Unit 1	Crystal Structure and Diffraction: Real lattices, packing fraction, reciprocal lattices, Brillouin zones. Diffraction by		T1, T3, R4	9	1		

	crystals - Ewald sphere construction, Bragg condition in k-space. Geometric structure factor and atomic form factor. Point defects, line defects and dislocations			
Unit 2	Lattice Dynamics: Vibrations of crystals with mono-atomic and diatomic basis. Brillouin zones. Optical modes and acoustic modes. Quantization of elastic waves. Phonon momentum. Neutron scattering by phonons. Phonon heat capacity. Phonon density of states. Einstein and Debye theories, thermal conductivity.	T1, T3, R5	9	2
Unit 3	Electronic Band Structure in Crystals: Drude theory of metals. Quantum free electron model of metals (Sommerfeld model). Nearly free electron theory. Brillouin zones. Electron effective mass. Density of states and band gap. Kronig-Penney model. Bloch theorem. Crystal momentum. Qualitative distinction between semiconductors and metals. Fermi surface of metals. Hall effect.	T1, T2, R5	9	3
Unit 4	Dielectric and Magnetic Properties of Solids: Macroscopic electric field and local electric field in solids. Polarizability and dielectric constant. Clausius-Mossotti relation. Dielectric-Ferroelectric phase transition. Landau theory. Piezoelectricity.	T-2, T-3	9	4
Unit 5	Diamagnetism – Langevin equation. Pauli paramagnetism in metals. Paramagnetism – Curie law. Ferromagnetism. Quantum mechanical nature of ferromagnetic interaction. Anti-ferromagnetic and ferromagnetic order.	T-1, T-2, R-4	9	5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. Solid State Physics, N. W. Ashcroft and N. D. Mermin (CBS Publishing Asia Ltd.). 2. Introduction to Solid State Physics, Charles Kittel (John Wiley and Sons.).			
Reference Book (Should)	1. Solid State Physics, A. J. Dekkar (Prentice Hall).			

Know) Ref. as (Rx) in the Syllabus	

Lab Course-Semester II		
Subject Code	AP 506L	
Subject Title	Photonics and Electronics Lab	
Credit	03	
Teaching Scheme	Lectures: 06 hours/week	
Evaluation Pattern	7. Continuous Evaluations: Experiments, Lab Records and Vive-voce 40 Marks (20 + 10 + 10) 8. Mini-Project and Term Work Evaluations: 10 Marks 4. One Final Evaluation at the End of the Term 50 Marks	
Total Marks	100 Marks	
Pre-requisite	Laser safety tutorials/video demonstration of Laser safety followed by written test	
About the Course	The Photonics and Electronics Laboratory course provides hands-on experience with the principles and applications of lasers, optical components, and electro-optic devices. It is designed to complement theoretical knowledge in optics and photonics with practical laboratory skills, emphasizing experimental methods, measurement techniques, and data analysis. This lab-centric course bridges the gap between classroom learning and real-world photonics applications, allowing students to explore the behaviour of light and optical systems through direct experimentation.	
Course Objectives	6. Understand the Principles of optical instrumentation 7. To conduct basic electronic experiments 8. Measure and Interpret Optical Phenomena 9. Develop Laboratory and Analytical Skills 10. To inculcate the habit of scientific writing among the students	
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create	
CO Title	Bloom's Level and Descriptor	
	CO1:	To make students familiar with advanced experiments in the field of lasers and electro-optics Understand (Level 2)
	CO2:	To make students realize usage of complex optical components and system design Analyze (Level 4)
	CO3:	To make students learn about real-time applications in optical communication Apply (Level 3)
	CO4:	To make students realize systematic data and report presentation in scientific methods Apply, Analyze (Level 3, Level4)
	CO5:	To analyze results obtained and verify with theory values and provide meaningful conclusion Evaluate (Level 5)

Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics									
		PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
	CO1	1	2				3	3	1	2
	CO2	1	3	2			3	3	1	2
	CO3	1	2	2	1	2	3	3	1	2
	CO4	1	3	3	1	3	2	3	1	2
	CO5	1	2	2	1	2	3	3	1	2
Syllabus Details:							Text/Ref. Books	Hrs	CO(s)	
	<u>List of Experiments:</u>									
	1	Beam Width Divergence of He-Ne/Diode Laser.						6	CO1	
	17.	Fiber optic link design						6	CO1	
	18.	Measurement of attenuation and Dispersion in optical Fibers						6	CO3	
	19.	Fiber Splicing						6	CO2	
	20.	Setting up of Mach-Zehnder Interferometer						6	CO2	
	21.	Characterization of Erbium-doped fiber amplifier						6	CO2	
	22.	Holography						6	CO2	
	23.	To study the VI characteristics of Diodes (simple and Zener Diode)						6	CO2	
	24.	To study the VI Characteristics of Transistors in CB, CE, CC modes (NPN & PNP Transistors)						6	CO3	
	25.	To study the VI Characteristics of MOSFETs						6	CO3	
	26.	To Study the Half, Full and Bridge rectifier						6	CO3	
	27.	To study the Voltage and Current regulation with a fixed load						6	CO4	
	28.	To study the clipping and clamping circuit						6	CO1-CO5	
	29.	To study the Characteristics of 741 OPAMPS						6	CO2	
	30.	To analyze the inverting and non-inverting amplifier						6	CO2	
Text Books (Must Know), Ref. as (Tx) in		6. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press,1989. References 7. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006. 8. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008 9. G. P. Agarwal, Fiber Optic Communication Systems, John Wiley & Sons, 2002. 10. Optical Fiber Communications – John M. Senior, PHI, 2nd Edition, 2002								

the Syllabus	
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	4. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007) 5. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000. 6. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998.

SEMESTER – III

CORE Courses-Semester I	
Subject Code	AP 508
Subject Title	Semiconductor Optoelectronic Devices
Credit	04
Teaching Scheme	Lectures: 03 hours/week + 1 hr tutorial/ practical
Evaluation Pattern	19. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 20. One Final Evaluation at the End of the Term 50 Marks 21. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks
Total Marks	100 Marks
Pre-requisite	B.Sc. Physics or Engineering Physics Knowledge
About the Course	Semiconductor Photonic Devices is the basic to advanced level subject which provides fundamental knowledge of different semiconductor material and its application in the photonic devices from sources to detectors. The course will give a explanation about working principles of devices such as LEDs, lasers, Detector, Photonic integrated circuit etc. The course will start with the introduction to properties of semiconductors, band structures, optical electronics, solving of Maxwell's equations, wave equation in anisotropic media, Uniaxial and biaxial crystals, the determination of dielectric constant, tensor and the 'index ellipsoid'. The Fresnel's equation also explored for Reflection and Refraction of plane waves. Later, it also covers the concepts of polarization of light through different optical components, like Polarizers, Quarter, Half, and Full waveplates, Beam splitters, wavelength filters, dichroic mirrors, Lenses, etc. It also deals with study of absorption and dispersion, Jones Calculus, Poincare sphere, with polarized and non-polarized lights.

	In unit 3, Electro-optical effects such as, Pockel and Kerr effects, Electro-optic modulators, switches, and scanners, E.O. effect in liquid crystals are discussed thoroughly and their applications in LCDs and SLMs.						
	Furthermore, the Acousto-optical effects, like, Strain waves in solids and liquids, the strain-optic tensor, theory of Raman-Nath and Bragg diffraction, small-angle and large-angle Bragg diffraction are explained with derivation. Acousto-optic devices, such as, modulators, deflectors, scanners, interconnections, acousto-optic tunable filters, are studied thoroughly.						
	Similarly, in Unit 5, the Magneto-optical effects, such as, Faraday effect, Gyrotropic permittivity, Kerr rotation, and Kerr ellipticity and its applications also been discussed. Finally, the current status of development and applications of this areas are covered.						
Course Objectives	This course is helping M. Tech. ‘Laser and Electro-optics’ students and similar branches to understand how the opto-electronic systems are working to fulfil the current needs of our society.						
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create						
CO Title				Level	Descriptor		
	CO1:	Understand the basics of Semiconductor Physics		1, 2	Remember; Understand		
	CO2:	Interpret all the optical properties and processes in semiconductors		2, 3	Understand; Apply		
	CO3:	Examine the working mechanism of different kinds of LEDs and LASERs		2, 3	Understand; Apply		
	CO4:	Illustrate the implementation of Modulation and Switching Devices		3, 4	Apply; Analyze		
	CO5:	Explain different types of photodiodes and photodetectors		3, 4, 5	Apply; Analyze; Evaluate;		
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics						
		PO1	PO2	PO3	PSO1	PSO2	PSO3
	CO1	3	2	1	3	1	2
	CO2	3	1	2	3	1	2
	CO3	1	2	3	3	1	2
	CO4	1	3	2	3	1	2
	CO5	1	2	3	3	1	2
Syllabus Details:				Text/Ref. Books	Hrs	CO(s)	
Unit 1	Review of Semiconductor Physics: Atoms, Molecules and Solids, Energy Bands, Density of States, Fermi-level, PN Junction, Homo and Hetero Junction, Quantum Wells. Semiconductor Optoelectronic materials, ~~Electron-hole pairs~~ , Interaction of Photons with Electrons and Holes			T1, T3, R4	9	1	
Unit 2	Light Emitting Diodes: The electroluminescence Process, LED materials, Device configuration and			T1, T3, R5	9	2	

	Efficiency, LED structures, LED performance characteristics, Frequency response and Modulation bandwidth. LEDs for display and Lighting.			
Unit 3	Semiconductor Lasers: Junction Laser Operating Principles, Threshold Current, Heterojunction Laser, Distributed Feedback Lasers and Distributed Bragg Reflector, Ring Lasers: Single and Double, Master Oscillator Power Amplifier. VCSELS and Laser Diode Arrays. , Laser Modulation Bandwidth.	T1, T2, R5	12	3
Unit 4	Modulation and Switching Devices: Analog and Digital Modulation of light sources, Franz-Keldysh and Stark-effect based Modulators, QW Electro-absorption modulator.	T-2, T-3	6	4
Unit 5	Photodetectors: Types of photodetectors, Photoconductors, Junction photodiode, PIN photodiode and APD, Noise in Photodetectors, Quantum Well IR Detectors, High Speed Measurements, Detectors for long wavelength operation, Wavelength selective detection, CCDs and PICs.	T-1, T-2, R-4	9	5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	7. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995). 8. G. Ghione, Semiconductor Devices for High-Speed Optoelectronics, Cambridge University Press (2009) 9. A. Yariv and P. Yeh, Photonics: Optical Electronics in Modern Communication, Oxford University Press (2007), 6 th Ed., Ch.15-17.			
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	10. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2 nd Ed. (2007), Ch.16, 17. 11. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3 rd Ed. (2021). 12. Streetman, Ben, and Sanjay Banerjee. Solid state electronic devices. Pearson Higher Ed, 2015.			

Lab Course-Semester I	
Subject Code	AP 509L
Subject Title	Advanced Photonics Lab
Credit	04
Teaching Scheme	Lectures: 06 hours/week
Evaluation Pattern	1. Continuous Evaluations: Experiments, Lab Records and Vive-voce 40 Marks (20 + 10 + 10) 2. Mini-Project and Term Work Evaluations: 10 Marks 5. One Final Evaluation at the End of the Term 50 Marks
Total Marks	100 Marks
Pre-requisite	Laser safety tutorials/video demonstration of Laser safety followed by written test
About the Course	The Advanced Photonics Laboratory course provides hands-on experience with the on various fiber optics systems, nonlinear optical systems, Optical characterization techniques etc.

Course Objectives	1. Understand the Principles of Optics and Optical sources such as Laser Operation 2. Gain Proficiency in Optical Alignment and Measurement 3. Operate and characterize various optical properties 4. Measure and Interpret Optical Phenomena 5. Develop Laboratory and Analytical Skills									
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create									
CO Title								Bloom’s Level and Descriptor		
	CO1:	To make students familiar with advanced experiments in the field of lasers and electro-optics					Understand (Level 2)			
	CO2:	To make students realize usage of complex optical components and system design					Analyze (Level 4)			
	CO3:	To make students learn about real-time applications in optical communication					Apply (Level 3)			
	CO4:	To make students realize systematic data and report presentation in scientific methods					Apply, Analyze (Level 3, Level4)			
	CO5:	To analyze results obtained and verify with theory values and provide meaningful conclusion					Evaluate (Level 5)			
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics									
		PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
	CO1	1	2				3	3	1	2
	CO2	1	3	2			3	3	1	2
	CO3	1	2	2	1	2	3	3	1	2
	CO4	1	3	3	1	3	2	3	1	2
	CO5	1	2	2	1	2	3	3	1	2
Syllabus Details:							Text/Ref. Books	Hrs	CO(s)	
	List of Experiments:									
1.	Characterization of Fiber Bragg Grating							6	CO1	
2.	Power Budget analysis using Optical time Domain Reflectometer (OTDR)							6	CO1	
3.	Study of Time Division Multiplexing of Digital Signal							6	CO3	
4.	Study of a wavelength Division Multiplexing WDM in optical Fiber link							6	CO2	
5.	Study of Add/Drop Multiplexer							6	CO2	
6.	Study of Bit Error rate and Eye Pattern analysis							6	CO2	
7.	Setting up third order nonlinear optical coefficient using Z-scan							6	CO2	

	8.	Design of Fiber optic sensor	6	CO2
	9.	Line coding, decoding and voice coding	6	CO3
	10.	Measurement of insertion losses of an isolator coupler and multiplexer	6	CO3
	11.	Beat length measurement in Birefringent Fiber	6	CO3
	12.	Laser Raman Spectroscopy Experiment	6	CO4
	13.	Optical Characterization Techniques		CO1-CO5
	14.	Lab project		CO1-CO5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	11. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press, 1989. References 12. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006. 13. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008 14. G. P. Agarwal, Fiber Optic Communication Systems, John Wiley & Sons, 2002. 15. Optical Fiber Communications – John M. Senior, PHI, 2nd Edition, 2002			
Reference Book (Should Know) Ref. as (Rx) in the Syllabus	7. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007) 8. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000. 9. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998.			

SEMESTER – IV

CORE Courses-Semester IV	
Subject Code	AP 616
Subject Title	Laser Applications
Credit	3
Teaching Scheme	Lectures: 03 hours/week
Evaluation Pattern	3. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 4. One Final Evaluation at the End of the Term 50 Marks

	5. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks						
Total Marks	100 Marks						
Pre-requisite	Fundamental knowledge in lasers						
About the Course							
Course Objectives							
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create						
CO Title					Level	Descriptor	
	CO-1	Familiarize to a variety of applications on lasers			L1, L2	Remember, Learn	
	CO-2	Interpret how laser-based metrological techniques work			L1, L2	Remember, Learn	
	CO-3	Understand laser spectroscopy applications			L3, L4	Apply, Analyse	
	CO-4	Investigate various methods of how a laser can be used for defence applications			L4, L5	Analyse, Evaluate	
	CO-5	Summarize different applications of lasers			L5, L6	Evaluate, Create	
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics						
		PO1	PO2	PO3	PSO1	PSO2	PSO3
	CO1	3	3	3	3	1	2
	CO2	3	2	3	3	1	2
	CO3	3	2	3	3	1	2
	CO4	3	3	3	3	1	2
	CO5	3	3	3	3	1	2
	1 - Slightly; 2 - Moderately; 3 - Substantially						
Syllabus Details:				Text/Ref. Books	Hrs	CO(s)	
Unit 1	Laser Metrology: Laser for measurement of distance, length, velocity, acceleration; rotation sensing; RLG and FOG.				6	CO1	
Unit 2	Laser Spectroscopy: IR absorption Spectroscopy, Laser Raman spectroscopy, Laser induced breakdown spectroscopy (LIBS), laser-induced fluorescence (LIF), Tunable diode laser spectroscopy (TDLS), Terahertz spectroscopy, Photoacoustic spectroscopy, Instrumentation in laser spectroscopy, Isotope Separation & Enrichment. Bio-Medical Application of Lasers				12	CO1	
Unit 3	Holography: Holographic interferometry and applications; Holography for non – destructive testing – Holographic components				6	CO1 CO2	
Unit 4	Industrial Application of Laser: Laser cutting, Laser welding, Laser drilling, Laser marking, Photolithography, Laser-based unmanned ground vehicles				9	CO3, CO4	
Unit 5	Defence Applications: Low power laser				12	CO4,	

	applications including Laser Range finders-LRF (DPSSL, Eye Safe & High PRF) & Laser Target Designators; Dazzlers, Laser Warning receivers, Infrared counter measures, Laser Guidance; Laser-based navigation; Laser-based imaging; Laser-based remote sensing: Laser radar, laser radar seekers, LIDAR basic concept and applications, AI based opt mechanics , 'Laser-based 3D printing and Directed Energy Weapon applications			CO5
Text Books (Must Know), Ref. as (Tx) in the Syllabus	1. J.F. Ready, Industrial Applications of Lasers. Academic Press, 1997 2nd Edition 2. G.K. Ackermann & J. Eichler, Holography: A practical approach, John Wiley & sons, 2008 3. H. Wichel, Laser Beam Propagation in the Atmosphere, SPIE Press 1990			
Reference Book (Should Know) Ref. as (Rx) in the Syllabus				

Core Courses-Semester IV	
Subject Code	AP 619
Subject Title	Terahertz Devices and Applications
Credit	03
Teaching Scheme	Lectures: 03 hours/week
Evaluation Pattern	4. Continuous Evaluations: Two Tests in each semester (20 Marks Each) 40 Marks 5. One Final Evaluation at the End of the Term 50 Marks 6. Lab Assignments/Mini-Project and Term Work Evaluations: 10 Marks
Total Marks	100 Marks
Pre-requisite	B.Sc. Physics or Engineering Physics Knowledge
About the Course	THz devices applications is a course giving a better understanding the less explored THz field in EM spectrum. The course provides information of properties of THz radiation, sources, detectors and different spectroscopic methods. It also explains the applications of THz in communication. The course will start with the introduction to properties of EM radiation and Maxwell equations. A introduction to THz is provided by discussing the properties of these rays (waves) in different media, advantages and disadvantages of the THz radiation Later, THz sources which works with different principles of Electronic (PINN diodes, HBT, HEMT), Optical based (Photomixers, NLO Crystals), Optoelectronic based (THz Quantum cascade Lasers, Photoconductive antenna),

	Different types of PCAs are discussed with the advantages of the PCA, the noise levels of the above explained THz sources are compared. In unit 3, different THz detectors are discussed based thermal (Hot electron Bolometer, Pyro-detector), Optical (Electro-optic sampling), electronic (Superconducting tuning circuitries, HEB heterodyne receivers), The concepts related to Terahertz MMICs: Theory and design, Terahertz detectors based on photonics are discussed thoroughly with the application-based comparison. Furthermore, the THz components such as Filters, Waveguides, Beam splitters, Beam combiners, polarizers, Mirrors, isolators, circulators, and Cameras, along with material properties, are explained briefly. The Fabrication Technologies of Metamaterial THz devices, Metamaterials and plastic fibers, HEMT cryogenic amplifiers: Theory and design, Antennas are explained. The application of Spintronic materials as THz components has also been discussed from the references of research articles. Finally, in Unit 5, THz applications in industry, imaging, and security are shown. The advantages and future scope of THz in 6G communication are explained thoroughly. The advantages of THz imaging on the current imaging setup are detailed with practical examples This course is helping M. Tech. ‘Laser and Electro-optics’ and ‘Sensor-Technology’ students and similar branches to understand how the THz field and its equipment are working to fulfill the current needs of our society.						
Course Objectives	- To impart basic knowledge of Terahertz Technology - To introduce the THz Sources, THz Detectors, THz Components. - To enable the students to understand application of THz technology in imaging, sensing and communication.						
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze; Level-5 Evaluate; Level-6 Create						
CO Title				Level	Descriptor		
	CO1:	Introduction to the concepts of terahertz technology		1, 2	Remember; Understand		
	CO2:	Analyze the working principle of different types of terahertz signal sources		2, 3	Understand; Apply		
	CO3:	Examine the working mechanism of different types of terahertz detectors		2, 3	Understand; Apply		
	CO4:	Illustrate the practical implementation of fabrication of components and circuits for terahertz systems		3, 4	Apply; Analyze		
	CO5:	Summarize different applications of terahertz technology for imaging, sensing and communications		3, 4, 5	Apply; Analyze; Evaluate;		
Summary of the Course Outcome	Course Outcome and Program Outcome Evaluation Metrics						
		PO1	PO2	PO3	PSO1	PSO2	PSO3
	CO1	3	1	2	3	1	2

		<table><tr><td>CO2</td><td>3</td><td>1</td><td>2</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO3</td><td>1</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO4</td><td>1</td><td>3</td><td>2</td><td>3</td><td>1</td><td>2</td></tr><tr><td>CO5</td><td>1</td><td>2</td><td>3</td><td>3</td><td>1</td><td>2</td></tr></table>	CO2	3	1	2	3	1	2	CO3	1	2	3	3	1	2	CO4	1	3	2	3	1	2	CO5	1	2	3	3	1	2			
CO2	3	1	2	3	1	2																											
CO3	1	2	3	3	1	2																											
CO4	1	3	2	3	1	2																											
CO5	1	2	3	3	1	2																											
Syllabus Details:				Text/Ref. Books	Hrs	CO(s)																											
Unit 1	Basics of Terahertz Technology: Electromagnetic radiation and propagation fundamentals, Introduction to terahertz technology, Background, Terahertz gap, Key technological issues for terahertz technology, Advantages and limitations of terahertz waves, Material properties at mm and sub-mm frequencies			T1, T3, R1	9	1																											
Unit 2	Terahertz Sources: Terahertz sources based on electronics: Diodes, transistors, resonant tunnelling diodes, vacuum electronics; Terahertz sources based on photonics: Non-linear crystals, quantum cascade lasers, plasma-based source; Terahertz sources based on optoelectronics: Photomixer, photoconductive antenna and its types; Noises at terahertz frequencies in different sources			T1, T3, R1	9	2																											
Unit 3	Terahertz Detectors: Terahertz detectors based on electronics: HOT electron bolometer, Heterodyne SIS receivers: Theory and design, Superconducting tuning circuitries, HEB heterodyne receivers: Theory and design, Terahertz MMICs: Theory and design, Terahertz detectors based on photonics			T1, T2, R2	9	3																											
Unit 4	Terahertz Components: Terahertz components: Metamaterials and plastic fibers, HEMT cryogenic amplifiers: Theory and design, Antennas, Filters, Waveguides, Beam Splitter, Beam Combiner, Polarizer, Mirrors, Isolator, Circulator, Cameras, Fabrication Technologies, Metamaterial THz devices, Spintronic THz components.			T-2, T-3	9	4																											
Unit 5	Terahertz Applications: Terahertz applications: Time domain Colinear and Non-colinear terahertz spectroscopy, Optical-pump-THz-probe Spectroscopy, Terahertz Imaging, Terahertz sensing and analysis, Terahertz wireless communication, Terahertz remote-sensing, 3D terahertz tomography system, Industrial applications, 6G Communication, Space Communication, Cutting-edge terahertz technologies			T-1, T-2, R-1	9	5																											
Text Books (Must Know), Ref. as (Tx) in the Syllabus		4. A. Rostami, H. Rasooli, H. Baghban, Terahertz Technology: Fundamentals and Applications, Germany, Springer, 2011. 5. R. E. Miles, P. Harrison, D. Lippens, Terahertz Sources and Systems “, Dordrecht: Kluwer, Springer, 2000. 6. K. Sakai, Terahertz Optoelectronics, Springer, 2004.																															
Reference Book (Should Know) Ref.		3. H.-J. Song, T. Nagatsuma, Handbook of Terahertz Technologies, Devices and applications, Pan Stanford Publishing Pte. Ltd., 2015.																															

as (Rx) in the Syllabus	4. D. Saeedkia, Handbook of Terahertz Technology for Imaging, Sensing and Communications, Woodhead Publishing, 2013.

Note: A few core/elective courses are common courses across the other programs, and details can be found at the respective programs.

M.Sc. Data Science

M.Sc. in Data Science

Program Overview

The **Master of Science in Data Science** (M.Sc.-DS) program at DIAT is designed to address the current market needs for highly skilled data science and data analytics professionals. The program is designed to help graduates gain skills and experience in designing, implementing, and transforming data sets into actionable knowledge. It provides students with the skills and knowledge needed to develop competencies in managing data science and analytics projects and working with data analytics tools and technologies. The program is aimed at helping to educate a new generation of information professionals capable of taking the leadership role by connecting the dots and using data to support strategic initiatives within the organization.

The Master of Science (M.Sc.) programme in Data Science is designed to meet such demands and train the next generation of data scientists. This is a two-year postgraduate interdisciplinary course spread over four semesters. Through this course, students will have the opportunity to gain hands-on experience with a variety of analytical tools available for the purpose of structuring large data sets to unearth hidden information and allow the organizations to build and sustain a long-term competitive advantage. The capstone of the programme is the on-job training program in first year and a guided project during second year in which students apply the acquired theoretical knowledge in data science to solve real-world business problems.

Need of Data Science: There are many applications, such as climate change, social media, healthcare, e-commerce, weather forecast, etc., that are generating massive amounts of data with volume, velocity, variety, veracity and value at an unprecedented scale. This has led to a critical demand of skilled professionals, Data Scientists, who can mine and interpret the data. Making sense of this massive data is a very difficult challenge for scientific, technological and industrial disciplines. Data science is concerned with the acquisition, storage, retrieval, processing and finally the conversion of data into knowledge where the quantum of data is very large.

Experiments, observations, and numerical simulations in many areas of science and business are currently generating terabytes (2^{40} bytes) of data, and in some cases are on the verge of generating petabytes (2^{50} bytes) and beyond. Today we are witnessing an exponential growth in the volume of data being produced and stored. This can be explained by the evolution of the technology that results in the proliferation of data with different formats from the most diverse domains (e.g. health care, banking, government or logistics) and sources (e.g. sensors, social networks or mobile devices). Facebook, for example, has an average of 4.75 billion

pieces of content shared among friends every day. Every business is generating enormous quantities of data that are too big to be processed and analyzed by the traditional Relational Database Management Systems (RDBMSs) and Data Warehouses (DWs) technologies, and thus are struggling to meet the performance and scalability requirements of the market. To alleviate these limitations, companies like Facebook, Google, Yahoo and Amazon etc. are making advancement by creating solutions and recruiting technologies to deal with these “Big Data” scenarios. Adopting Big Data-based technologies not only mitigates the problems presented above, but also opens new perspectives that allow extracting value from Big Data. Big Data-based technologies are being applied with success in multiple scenarios like in: (1) e-commerce and marketing, the crowds do on the web allow identifying trends that improve campaigns, evaluate personal profiles of a user, so that the content shown is the one he will most likely enjoy; (2) government and public health, allowing the detection and tracking of disease outbreaks via social media or detect frauds; (3) transportation, industry and surveillance, with real-time improved estimated times of arrival and smart use of resources. Hence, understanding the science behind data is the need of the hour. There are three disciplines that forms the core of Data Science and are inter-related: Computer Science, Mathematics and Statistics. An important difference between Data Science and Computer Science is that Data Science heavily uses the more continuous aspects of Mathematics together with extensive Statistics. Data Science is the combination of Statistics, Mathematics, Programming, Problem-Solving, capturing data in ingenious ways, the ability to look at things differently, and the activity of cleansing, preparing and aligning the data.

Organization of M.Sc programme:

This programme is of four-semester duration. The first semester is comprised of four theory courses and a Lab course where each course either has a practical/tutorial component or a lab class. The respective course instructor will give assignments / practical problems based on the course content which will be executed in the Lab. The practice problems can be solved by using Advanced Data structures (C / C++) / MATLAB / MATHEMATICA / Simula8 / Maplesim / SPSS / R / Python / Extend Sim. etc., The department has the licensed version of all these softwares and are available to student. The first semester contains all courses as compulsory, while the second and the third semester has two core courses and an option to choose three elective courses. The interested students can take any course as an audit course; however, no credits will be counted for attending an audit course. The first semester also includes an institute level compulsory course on research methodology. An additional 120 Hrs of mandate On-Job

Training/Field Project/Internship is offered in the first year of M.Sc. Data Science curriculum to provide students with valuable practical experience and enhance their skill development. A **mini-guided project is introduced in the third semester which gives an insight to the student on how to do the literature survey, how the theoretical courses are applicable in practical implementation like in real life situations / industry, problem identification, report writing, presentation skills etc. under the guidance of respective supervisor(s).**

The final semester is entirely dedicated to the dissertation work. The course evaluation process is comprised of two assessment tests, an internal evaluation and a final semester examination. Furthermore, after the completion of second semester, the students are encouraged to do a summer internship for about one and half month at their place of choice or any organization to identify their project work. The department faculty and respective supervisor will encourage and support students to build their projects in relevance to DRDO labs / other premier institutes and industry. However, the department will not sponsor such projects; except official arrangements, like issuing NOC certificate etc. The internship/project related arrangements and expenses are to be entirely borne by student at their own responsibility. Every student is required to submit a thesis report and present their project work to the thesis evaluation committee (the thesis evaluation committee will be formed as per the rules and regulations of DIAT PGC guidelines) at the end of the final semester.

Eligibility Criteria for Admission to join this programme

M. Sc. (Data Science)	Minimum Educational Qualifications: The candidate must have a qualified Bachelor's degree in any branch or discipline / BCA / B. Mathematics / B. Statistics.
	Essential subjects in Bachelor's Degree along with minimum duration: a) Mathematics/Statistics as a subject for at least two years/four semesters b) Qualified JAM Exam Paper in Mathematical Statistics (MS) or Mathematics (MA). c) For Self-financed and Sponsored candidates JAM is exempted.

Programme objectives and Outcomes.

Sl. No.	Programme Educational Objectives (PEO's)
PEO1	To enable learners to develop knowledge and skills in current and emerging areas on various theoretical and practical aspects of data science.
PEO2	Ability to apply knowledge of mathematics, probability and statistics, computer science and solve problems.

PEO3	To demonstrate expert / impart knowledge of data science, statistics, tools, techniques and technologies of data science.
PEO4	To train and develop in depth understanding of the key technologies in data science such as database management, data mining, data visualization techniques like: Hadoop, R, Python, and statistics, complex machine learning algorithms to build predictive models for a wide range of application domains
PEO5	To develop project-management, critical-thinking, problem-solving, formulate and implement a novel research idea and decision-making skills in the field of data science.

Sl. No.	Programme Outcomes (PO)
PO1	An ability to independently carry out research /investigation and development work to solve practical problems
PO2	An ability to write and present a substantial technical report/document
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

Sl. No.	Programme Specific Outcomes (PSO)
PSO1	Problem Analysis and Design: Ability to identify analyse and design solutions for data Science problems using fundamental principles of mathematics, Statistics, computing sciences, and relevant domain disciplines.
PSO2	Modern software tool usage: Acquire the skills in handling data analytics programming tools towards problem solving and solution analysis for domain specific problems.
PSO3	Applications in Multidisciplinary domains: Understand the role of statistical approaches and apply the same to solve the real-life problems in the fields of data science. Apply the research-based knowledge to analyse and solve advanced problems in data science.

Semester I:

Sl. No.	Course Code	Course Name	Contact hours / week			Credits
			L	T	P	
8.	AM501	Computational Linear Algebra	3	1	0	4
9.	AM502	Data Structures and Algorithms	3	1	0	4
10.	AM604	Advanced Statistical Techniques	3	0	0	3
11.	AM504	Foundations of Data Science	3	0	0	3
12.	AM505L	Computational Lab in Python and R	0	0	4	2
13.	RM501	Research Methodology	3	1	0	4
		TOTAL	15	03	04	20

Semester II:

Sl. No.	Course Code	Course Name	Contact hours /week			Credits
			L	T	P	
1.	AM521	Artificial Intelligence and Machine Learning	3	0	2	4
2.	AM522	Big Data Analysis and Algorithms	3	0	0	3
3.		Elective-1	3	0	0	3
4.		Elective-2	3	0	0	3
5.		Elective-3	3	0	0	3
6.	OJT/FP	On-Job Training/Field Project (120 Hrs)	0	0	8	4
		TOTAL	15	00	05	20

Semester III:

Sl. No.	Course Code	Course Name	Contact hours / week			Credits
			L	T	P	
1.	AM531	Time Series Analysis & Forecasting Methods	3	0	2	4
2.	AM532	Deep Learning	3	0	0	3
3.		Elective - 1	3	0	0	3
4.		Elective - 2	3	0	0	3
5.		Elective - 3	3	0	0	3
6.	RP541	Guided Project - I	12**			06
		TOTAL	15	00	14	22

Semester IV:

Sl. No.	Course Code	Course Name	Contact hours / week		Credits
			L	T / P	
1.	RP542	Guided Project - II	36**		18
		TOTAL	36		18

****Contact Hours / week: -**

- ✓ Lecture – L (Theory) / Tutorial (T) means - one contact hour for one credit per week
- ✓ Practical (P) (Lab session) / means two contact hours for one credit per week

List of Electives are given below: Few of the elective courses are listed below. However, the students are allowed to choose Elective Courses (necessary permission / approval of the department is required to suggest the relevance of the course / programme) of various departments of their respective programmes, which will be updated time to time and it will be made available in the DIAT-PG Course of Study book. A maximum of 6 credits can be opted by students as Professional Electives through NPTEL/SWAYAM/MOOC courses.

Sl. No.	Course Code	Course
1.	AM610	Data Analysis and Visualization
2.	AM625	Image and Video Analytics
3.	AM627	Information Theory and Coding
4.	AM628	Computational Number Theory and Cryptography
5.	AM635	Finite Elements: Theory and Algorithms
6.	AM636	Cloud Computing
7.	AM637	Generative AI
8.	AM638	Reinforcement Learning
9.	AM639	Deep Learning for Computer Vision
10.	AM640	AI for Medical Image Analysis
11.	AM641	Accelerated Computing
12.	AM642	Computer Vision with Pattern Recognition
13.	AM643	Database Systems
14.	AM644	Digital Twins
15.	AM523	Optimization Techniques
16.	AM524	Regression Analysis and Predictive Modelling
17.	AM525	Measure Theory and Multivariate Calculus
18.	AM526	Functional Analysis
19.	AM533	Multivariate Data Analysis
20.	AM534	Digital Image Processing
21.	AM536	Data Mining Techniques
22.	AM537	Mathematical Cryptography
23.	CS541	Natural Language Processing
24.	CSMSCD542	Pattern Recognition
25.	CSMSCD543	Cloud Computing
26.	CSMSCD544	Computer Vision
27.	CSMSCD545	Computer Forensics
28.	CSMSCD546	IoT Analytics
29.	CSMSCD547	Distributed Databases
30.	CSMSCD548	Data Security
31.	CSMSCD549	Advanced Database Management Systems
32.	CSMSCD550	Computer Organization and Architecture
33.	CSMSCD551	Generative AI

34.	CSMSCD552	Advanced NLP with LLMs
35.	TMMSCD550	Business Economics and Financial Analysis
36.	SRMSCD560	Symbolic AI
37.	SRMSCD561	Data-driven Robotics and Learning Control
38.	MOOC / NPTEL / Department Courses	

List of NPTEL Courses offered:

S.No.	Name of Course	Duration
1.	Data Structures and Algorithms Design	12 weeks
2.	Computer Architecture	
3.	Advanced Distributed Systems	
4.	Distributed Optimization and Machine Learning	
5.	Foundations of Virtual Reality	
6.	Artificial Intelligence: Search Methods for Problem Solving	
7.	Introduction to Machine Learning	
8.	Reinforcement Learning	
9.	Deep Learning for Computer Vision	
10.	Parameterized Algorithms	
11.	Getting Started with Competitive Programming	
12.	Applied Accelerated Artificial Intelligence	
13.	Social Network Analysis	
14.	Social Networks	
15.	The Joy of Computing using Python	
16.	Discrete Mathematics	
17.	Deep Learning - IIT Ropar	
18.	Cloud Computing	
19.	Software Project Management	
20.	Programming In Java	
21.	Stochastic Approximation: Theory and Applications	
22.	Computational Complexity	
23.	Cyber Security and Privacy	
24.	Privacy and Security in Online Social Media	
25.	Responsible & Safe AI Systems	
26.	Practical Cyber Security for Cyber Security Practitioners	
27.	Randomized Methods in Complexity	
28.	Computational Arithmetic - Geometry for Algebraic Curves	
29.	Discrete Mathematics - IITB	
30.	Secure Computation: Part II	
31.	Linear Algebra Through Geometry	
32.	Mathematical Foundations for Machine Learning	
33.	Statistical Learning for Reliability Analysis	
34.	Problem Solving through Programming in C	
35.	Ethical Hacking	

36.	Computer Vision	
37.	Programming in Modern C++	
38.	Introduction to Industry 4.0 and Industrial Internet of Things	
39.	Introduction to Internet of Things	
40.	Data Structure and Algorithms using Java	
41.	Introduction to Algorithms and Analysis	
42.	Algorithmic Game Theory	
43.	Approximation Algorithm	
44.	Computer Architecture and Organization	
45.	Real-Time Systems	
46.	Second Level Algorithms	
47.	Artificial Intelligence: Concepts and Techniques	
48.	Introduction to Large Language Models (LLMs)	
49.	Machine Learning (ML) in Hindi	
50.	Applied Linear Algebra for Signal Processing, Data Analytics and Machine Learning	
51.	Real-Time Digital Signal Processing	
52.	Digital Image Processing	
53.	Pattern Recognition and Application	
54.	Optimization Theory and Algorithms	
55.	Neural Networks for Signal Processing - I	
56.	Machine Learning and Deep Learning - Fundamentals and Applications	
57.	Mathematics for Machine Learning	
58.	Geographic Information System	
59.	Soft Skills	
60.	Public Speaking	
61.	Application of Forecasting, Regression and Time Series Models	
62.	Project Management for Managers	
63.	Data Analysis & Decision Making - II	
64.	Advanced R Programming for Data Analytics in Business	
65.	Regression Analysis	
66.	Foundations of R Software	
67.	Foundations of R Software (In Hindi Language)	
68.	Descriptive Statistics with R Software	12 weeks
69.	Numerical Methods for Engineers	
70.	Bandit Algorithm (Online Machine Learning)	
71.	Essentials of Topology	
72.	Multi-Core Computer Architecture	
73.	Design & Implementation of Human-Computer Interfaces	
74.	Programming in Modern C++	
75.	Artificial Intelligence for Economics	
76.	Approximate Reasoning using Fuzzy Set Theory	
77.	Real Analysis II	
78.	Mathematical Methods and its Applications	
79.	Matrix Analysis with Applications	
80.	Essential Mathematics for Machine Learning	

81.	Introduction to Fuzzy Set Theory, Arithmetic and Logic	
82.	Introduction to Methods of Applied Mathematics	
83.	Matrix Computation and its Applications	
84.	Computational Commutative Algebra	
85.	EXCElIng with Mathematical Modeling	
86.	A Basic Course in Number Theory	
87.	Ordinary Differential Equations	
88.	A Primer to Mathematical Optimization	
89.	Category Theory	
90.	Introduction to Algebraic Geometry	
91.	Partial Differential Equations - IITB	
92.	An introduction to Point-Set-Topology Part - II	
93.	Galois Theory	
94.	Linear Algebra	
95.	An Introduction to Smooth Manifolds	
96.	Introductory Course in Real Analysis	
97.	Rings and Modules	

Evaluation for OJT/FP and Lab Examination

The OJT/FP is evaluated for 100 Marks (4 Credits) and the evaluation process is carried out before the start of Sem-III or after completion of theory exam papers (Sem II) as per the following mentioned criteria: 50 Marks by External Supervisor and 50 Marks by Departmental Committee headed by HoD/Director.

Further, the examination for Lab course will be conducted by the respective instructor for 50 marks and final marks statement will be submitted to CoE.

Guidelines for M.Sc. (Data Science) Guided Project I and II

All the candidates of M. Sc. (Data Science) are required to submit a project report based on the work done by him/her during the project period.

The department will allot the supervisor / guide to each student as per DIAT norms however preference will be given by considering the students' choice to work under the supervisor and areas of research. The Project topics should be based on syllabus or beyond. The evaluation for RP541 and RP542 is for 150 marks (6 credits) and 450 marks (18 credits) respectively, and is conducted after completion of theory exam papers (Sem III and Sem IV resp.) as per the schedule of CoE. The evaluation for Guided Project-II will be based on the project report and presentation by the student to the evaluation committee constituted as per the DIAT PGC guidelines.

The guided project-I i.e. RP 541 is evaluated for 150 Marks as per the below mentioned criteria.

	Evaluation criteria	Marks
Part 1	Three reports are to be submitted and each report carries 10 Marks. The report should contain under the below mentioned points are to be covered. ➤ Specify the broad topic of your project based on the relevant field which you studied in this curriculum or industry related or literature survey etc. ➤ Study minimum 12 to 15 quality research papers based on the selected topic. ➤ Prepare the SWOT analysis of selected research papers / reports. ➤ Identify the research problem which may helpful to final dissertation in the final semester. ➤ Propose your novelty / improvement in terms of algorithm/new feature. ➤ Design the architecture for the proposed problem. ➤ Design a set of experiments to be carried out for the proposed problem. ➤ Perform the experimental analysis (in Python language or any other programming languages). ➤ Write a short research paper based on your contribution.	30 Marks (Supervisor will submit the marks)
Part 2	Submit the project report followed by Presentation / Viva. It will be conducted based on the report submitted by the student. The Viva Voce Committee (as per DIAT-PGC guidelines) will evaluate the presentation. <u>Summary of the Project Report (As per DIAT-PGC Rules & Regulations)</u> All students must submit a Summary of the Project Report separately with the project report. Summary, preferably, should be of about 3-4 pages. The content should be as brief as which will explain the objective and implementation of the project that the candidate is going to take up. The write up must adhere to the guidelines and should include the following ➤ Name / Title of the Project ➤ Statement about the Problem ➤ Why are the particular topic chosen? ➤ Objective and Scope of the Project ➤ Methodology (including a summary of the project) ➤ Hardware & Software to be used	120 Marks (Viva Voce Committee)

	➤ Testing Technologies used ➤ What contribution would the project make? <u>TOPIC OF THE PROJECT-</u> This should be explicitly mentioned at the beginning of the Synopsis. Since the topic itself gives a peep into the project to be taken up, candidate is advised to be prudent on naming the project. This being the overall impression on the future work, the topic should corroborate the work. <u>OBJECTIVE AND SCOPE:</u> This should give a clear picture of the project. Objective should be clearly specified. What the project ends up to and in what way this is going to help the end user has to be mentioned. <u>PROCESS DESCRIPTION:</u> The process of the whole software system proposed, to be developed, should be mentioned in brief. This may be supported by DFDs / Flowcharts to explain the flow of the information. <u>RESOURCES AND LIMITATIONS:</u> The requirement of the resources for designing and developing the proposed system must be given. The resources might be in form of the hardware/software or the data from the industry. The limitation of the proposed system in respect of a larger and comprehensive system must be given. <u>CONCLUSION:</u> The write-up must end with the concluding remarks-briefly describing innovation in the approach for implementing the Project, main achievements and also any other important feature that makes the system stand out from the rest.	
Total 150 Marks along with grade will be submitted to the CoE by the constituted committee.		

FIRST SEMESTER

Course Code	Course Name	L – T – P	Credits
AM501	Computational Linear Algebra	3-1-0	4

Course Objectives:

The course focuses on iterative techniques for solving large sparse linear systems of equations which typically stem from the discretization of partial differential equations. In addition, computation of eigenvalues, least square problems and error analysis will be discussed.

Course Contents

Unit - 1: Matrices and Its Properties

Matrices and Gaussian Elimination, Matrix Notation, Matrix Multiplication, Triangular Factors, Row Exchanges, Inverses and Transposes, Special Matrices and Applications, IEEE Floating Point Arithmetic, Analysis of Round-off Errors

Unit - 2: Vector Spaces

Vector Spaces, Subspaces, Solving $Ax = 0$, and $Ax = b$, Linear Independence, Basis and Dimension, Four Fundamental Subspaces, Graphs and Networks, Linear Transformations

Unit - 3: Orthogonal and Projections

Orthogonality - Orthogonal Vectors and Subspaces, Cosines and Projections onto Lines, Least Squares, Orthogonal Bases and Gram - Schmidt, Fast Fourier Transform

Unit – 4: Eigenvalue Problems

Overview of eigenvalue problems – Diagonalization of a Matrix, Difference Equations and Powers, Differential Equations, Complex Matrices, Similarity Transformations, Positive Definite Matrices - Tests for Positive Definiteness, Spectral Decomposition,

Unit – 5: Matrix Decomposition

Eigenvalues and Singular Values - Schur's Decomposition, Reduction of Matrices to Hessenberg and Tridiagonal Forms; Power, Inverse Power and Rayleigh Quotient Iterations; QR Algorithm, Implementation of Implicit QR Algorithm; Sensitivity Analysis of Eigenvalues; Reduction of Matrices to Bi-diagonal Forms, QR Algorithm for SVD, Singular Value Decomposition (SVD)

Unit – 6: Various Methods for Linear Systems

Computation with Matrices - Matrix Norms, Condition Numbers, Stability, Sensitivity Analysis and Ill-Conditioning; Linear systems – Direct Methods: Back Substitution, LU factorization, Gaussian Eliminations, Cholesky Factorization, QR Factorization, Stability and Sensitivity Analysis; Iterative Methods: Jacobi, Gauss-Seidel and Successive Overrelaxation Methods; Krylov Methods: Linear least-squares - Gram- Schmidt Orthonormal Process, Rotators And Reflectors, Moore- Penrose Inverse, Rank Deficient Least-Squares Problems, Sensitivity Analysis, Arnoldi and GMRES, CG (conjugate gradients).

Course Outcomes

After completing this course, the students develop the skill set to:

CO1: explain and fluently apply fundamental linear algebraic concepts such as matrix norms, Eigen- and

singular values and vectors; CO2: estimate stability of the solutions to linear algebraic equations and eigenvalue problems; recognize matrices of important special classes, such as Normal, Unitary, Hermitian, Positive-definite and select efficient computational algorithms based on this classification; CO3: implement the above algorithms on a computer, verify your code, and understand the behavior of your code through the underlying theory. CO4: understand the effects of finite precision on numerical computing, including stability, conditioning, and error types. CO5: evaluate the complexity (computational cost) of the covered numerical algorithms.
Text Books
3. Linear Algebra and Its Applications - by Gilbert Strang, 4th Edition, Thomson Brooks/Cole. 4. Numerical Linear Algebra - by L. N. Trefethen and David Bau, SIAM, 1997. 5. Matrix Analysis and Applied Linear Algebra - by Carl D. Meyer, SIAM, 2000 6. Fundamentals of Matrix Computation - by D. S. Watkins, 2nd Ed., Wiley, 2002.
Reference Books
4. Applied Numerical Linear Algebra - by J.W. Demmel, SIAM, 1997. 5. Matrix Computation - by G. H. Golub and C.F. Van Loan, 3rd Edn., Hindustan book agency, 2007. 6. Numerical Linear Algebra and Applications - by B. N. Datta, 2nd Edn., SIAM, 2010. 7. Numerical Linear Algebra - by Allaire, Grégoire, Kaber, Sidi Mahmoud, Springer (2008)
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Advanced Linear Algebra by Prof. Premananda Bera, IIT Roorkee

Course Code	Course Name	L – T – P	Credits
AM502	Data Structures and Algorithms	3-1-0	4
Course Objectives: This course aims to develop a strong foundation in the design and analysis of efficient algorithms, introduce abstract data types and their practical use in solving real-world problems. Apply algorithmic strategies such as divide and conquer, dynamic programming, and greedy methods. Analyze algorithm complexity and performance, with emphasis on time and space trade-offs. Implement data structures and algorithms in Python (or another relevant language) for data-centric applications.			
Course Contents			
Unit – 1: Linear Data Structures Introduction to Data Structures – Fundamental Elements – Asymptotic Notations: Big-Oh, Omega and Theta – Best, Worst and Average case Analysis: Definition and an example -Arrays and its representations – Stacks and Queues – Linked lists - Singly Linked List - Doubly linked list - Linked list-based implementation of Stacks and Queues – Evaluation of Expressions. Unit – 2: Non-Linear Data Structures Trees: Introduction to Trees – Basic concepts - Binary Trees – Binary tree representations (Array and list) and Traversals Techniques (Preorder, Inorder, Postorder) – Succinct Data Structures: Overview – Level order representation of Binary Trees – Rank and Select – Subtrees. Graphs: Definitions, Terminologies, Matrix and Adjacency List Representation of Graphs, Elementary Graph operations, Traversal methods:			

Breadth First Search and Depth First Search. Data Structures for Graphs, Graph traversals-DFS and BFS, Applications of Graphs-Minimum cost spanning tree using Kruskal's algorithm, Dijkstra's algorithm for Single Source Shortest Path Problem

Unit – 3: Search Tree Structures and Priority Queues

Binary Search Trees – AVL Trees – Splay Trees - Priority Queues – Heaps implementations – Binary Heap.

Unit – 4: Sorting and searching

Sorting Algorithms: Basic concepts - Bubble Sort - Insertion Sort - Selection Sort - Quick Sort – Shell sort- Heap Sort - Merge Sort - External Sorting. Searching: Linear Search, Binary Search.

Unit – 5: Indexing and Disjoint Sets

Indexing: Hashing - Hash Functions – Separate Chaining – Open Addressing: Linear Probing- Quadratic Probing- Double Hashing- Rehashing – Extendible Hashing. Disjoint Sets: Basic data structure - Smart Union Algorithms - Path Compression.

Course Outcomes

After completing this course, the students develop the skill set to:

- CO1:** analyze the time and space complexity of algorithms using asymptotic notations.
- CO2:** implement and manipulate linear and non-linear data structures effectively.
- CO3:** apply appropriate searching and sorting algorithms to solve data processing problems.
- CO4:** design efficient algorithms using greedy, divide and conquer, and dynamic programming paradigms.
- CO5:** solve complex real-world problems using advanced graph algorithms and optimize their performance.

Text Books

1. Fundamentals of Data Structures in C by Ellis Horowitz, S. Sahni, and Susan Anderson Freed, Universities Press, 2nd Ed., 2015.
2. Data Structures using C by A. S. Tanenbaum, Y. Langsam, and M.J. Augenstein, PHI/Pearson Education, 2008.
3. Introduction to Algorithms by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein, MIT Press, 3rd Ed., 2009.
4. Algorithms Unlocked by Thomas H. Cormen, MIT Press, 2013.

Reference Books

1. Data Structures using C by Y. Langsam, M. J. Augenstein and A. M. Tanenbaum, , Pearson Education Asia, 2004.
2. Data Structures: A Pseudocode Approach with C by R. F. Gilberg and B.A. Forouzan, Course Technology Inc., 2nd Ed., 2004.
3. The Algorithm Design Manual by Steven S. Skiena, Springer, 2nd Ed., 2008.
4. Algorithms: Part I by Sedgewick Robert, Wayne Kevin, Addison-Wesley Professional, 4th Ed., 2011.
5. *An Introduction to the Analysis of Algorithms* by Robert Sedgewick and Philippe Flajolet, Addison-Wesley Professional, 2nd Ed., 2013.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. <https://courses.csail.mit.edu/6.851/spring12/scribe/lec12.pdf> (Fusion Data Structures)
2. <https://nptel.ac.in/courses/106102064/>

Course Code	Course Name	L – T – P	Credits
AM604	Advanced Statistical Techniques	3-0-0	3
Course Objectives: The goal of this course is to inculcate the knowledge on probabilistic concepts and its applications, descriptive statistics, various distribution and its variants, learn the sampling techniques and understand the concept of inferential statistics for decision making.			
Course Contents			
Unit – 1: Probability Theory Sample Spaces- Events - Axioms – Counting - Conditional Probability and Bayes’ Theorem – The Binomial Theorem – Random variable and distributions: Mean and Variance of a Random Variable-Binomial-Poisson-Exponential and Normal distributions.			
Unit – 2: Sampling Distributions & Descriptive Statistics The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population, Sampling distributions (Chi-Square, t, F, z). Test of Hypothesis- Testing for Attributes –Mean of Normal Population – One-tailed and two-tailed tests, F-test and Chi-Square test - - Analysis of variance ANOVA – One way and two-way classifications.			
Unit – 3: Regression modeling for Normal response and quantitative explanatory Introduction to Statistical modelling, Variables, Simple and Multiple regressions, Model building and validation Comparison of regressions.			
Unit – 4: Stochastic process Basic idea of random processes, Stationary, Markov processes, Markov chains and applications, Introduction to ergodicity			
Course Outcomes			
After completing this course, the students will be able to: CO1: Understand the fundamental concepts of probability and statistics such as Axioms, addition law, conditional probability, Baye’s principle etc., and their real-life application to predict the data. CO2: Understand the importance of Probability Distributions such as Binomial, Poisson, Normal and Exponential Distributions and their properties and problems on special probability distributions. CO3: Analyze and appreciate the statistical theory behind Curve fitting, regression modeling and Chi Square Test, student test & Fisherman test. CO4: Understand the theory behind Design and Analysis of Experiments: Need for conducting Experiments, and their possible applications.			
Text Books			
1. Stochastic Process, 3rd Ed., 2010, J. Medhi, New Age Science Ltd. 2. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Academic Press. 3. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley			

India Pvt. Ltd.

Reference Books

17. All of Statistics: A Concise Course in Statistical Inference, 2003, Larry Wasserman, Springer.
18. Introduction to Statistical Modelling, 2010, W. J. Krzanowski, Oxford university press.
19. Schaum's outlines Probability and statistics, 4th Ed., 2013, Murray R. Spiegel, John Schiller, R Alu Srinivasan, Tata McGraw Hill
20. Learning R, O'Reilly, 2013, Richard Cotton.
21. Introductory statistics with R, 2008, Dalgaard, Peter Springer Science & Business Media.
22. A Handbook of Statistical Analysis Using R, Second Edition LLC, 2014, Brain S. Everitt.
23. Introduction to Probability and Statistics for Engineers and Scientists", 4th Ed., 2009, Sheldon M. Ross, Academic Press.
24. R Cookbook, O'Reilly, 2011, Paul Teetor.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Essentials of Data Science with R: Probability and Statistical Inference by Prof. Shalabh, IIT Kanpur

Course Code	Course Name	L – T – P	Credits
AM504	Foundations of Data Science	3-0-0	3

Course Objectives:

This course aims to provide working knowledge of Python Programming, and basic understanding of the concepts of strings, lists, dictionaries, line properties, different setter methods and practical uses of methods, overloading and polymorphism. It also aims to get students familiar with different conditional statements, plots and implementation of recursive functions.

Course Contents

Unit – 1: Introduction to Python

Python Basics, Variables, Expressions and Statements: Assignment Statements, Variable Names, Expressions Statements, Order of Operations; Functions: Function Calls, Composition, Adding New Functions, Definitions and Uses, Flow of Execution; Conditionals and Recursion: Floor Division and Modulus, Boolean Expressions, Logical Operators, Conditional Execution; Fruitful Functions: Return Values, Incremental Development, Composition, Boolean Functions: Iteration: Reassignment, Updating Variables, While Statement, Break, Square Roots

Unit – 2: Advanced Concepts in Python

Strings: String Length, For Loop Traversal, Searching, Looping and Counting; Lists: Traversing a List, List Operations, Deleting Elements; Dictionaries: Looping and Dictionaries, Reverse Lookup, Dictionaries and Lists, Global Variables; Tuples: Assignment, Return Values, Variable-Length Argument Tuples, Lists and Tuples, Dictionaries and Tuples; Files: Reading and Writing, Format Operator, Filenames and Paths, Catching Exceptions; Classes and Objects: Programmer Defined Types, Attributes,

Rectangles, Instances As Return Values. Classes And Methods: Object Oriented Features, Init() Method, Str Method, Operator Overloading, Polymorphism, Inheritance

Unit – 3: Data Manipulation using Python Libraries

Introduction to NumPy: the World of Arrays with Numpy, Computation of NumPy Arrays, Aggregations, Comparisons, Sorting Arrays, Structured Data; Data Manipulation with Pandas: Installing and Using Pandas, Introducing Pandas Objects, Data Indexing and selection, Operating on Data in Pandas, Handling Missing Data, Hierarchical Indexing, Combining Plotting Data using Matplotlib: Plotting using Matplotlib, Customization of Plots: Marker, Colour, Linewidth and Line Style, The Pandas Plot Function (Pandas Visualization), Plotting a Line Chart, Plotting Bar Chart, Plotting Histogram, Plotting Scatter Chart, Plotting Quartiles and Box Plot, Plotting Pie Chart.

Unit – 4: Data Visualization

Making Sense of Data through Advanced Visualization: Area plots, Bubble charts, Hexagon bin plots, Trellis plots, 3D plot of a surface; Understanding Data Types in Python; Empowering Data Analysis with Pandas, Data Cleansing, Data Operations; Visualization with Matplotlib: Simple Line Plots, Simple Scatter Plot, Visualizing Errors, Density and Contour Plots, Histograms, Binnings and Density. Customization with Matplotlib: Customizing Plot Legends, Customizing Colorbars, Multiple Subplots, Text and Annotations, Customizing Ticks, Configuration and Stylesheets, Three-Dimensional Plotting, Geographic Data with Basemap and Visualisation with Seaborn

Unit – 5: Data Ethics and Recent Trends

Data Science Ethics, Ethical Considerations in Data Collection And Usage – Doing Good Data Science – Owners of the Data - Valuing Different Aspects of Privacy - Getting Informed Consent - The Five Cs – Diversity – Inclusion – Future Trends – Privacy Issues and Data Protection Regulations – Bias and Fairness in Machine Learning Models – Responsible AI Practices

Course Outcomes

After completing this course, the students will:

- CO1:** gain a solid understanding of key concepts and principles in data science
- CO2:** develop strong programming skills in Python and learn how to leverage Python libraries such as NumPy, Pandas, Matplotlib, and Scikit-learn for data manipulation, analysis, and modeling.
- CO3:** acquire the skills to understand the data and learn techniques to summarize data to gain insights and identify patterns
- CO4:** understand various statistical concepts and techniques needed for data analysis.
- CO5:** develop an understanding of various algorithms for classification, regression, clustering and dimension reduction, and learn about evaluation metrics and techniques for model selection and tuning.

Text Books

1. Mastering Python for Data Science - by Samir Madhavan, PACKT Publishing, 2015.
2. Think Python - by Allen Downey O'Reilly Publications, 2nd Edition, 2016.
3. Python Data Science Handbook Essential Tools for Working with Data – by Jake Vander Plas, O'Reilly Media, 1st edition, 2016.
4. Ethics and Data Science - by D J Patil, Hilary mason, Mike Loukides, O' Reilly, 1st Edition, 2018.
5. An Introduction to Statistical Learning: with Applications in R - by Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, Springer, 1st edition, 2013.

Reference Books	
1. Data Science from Scratch: First Principles with Python - by Joel Grus, O'Reilly, 1st Edition, 2015. 2. Data Analytics using Python - by Bharti Motwani, Wiley, 1st Edition, 2020. 3. Python Data Science Essentials - by Alberto Boschetti and Luca Massaron, Packt publishing, 3rd Edition, 2018. 4. Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython - by Wes McKinney, O'Reilly Media, Inc., 2nd edition, 2017. 5. Programming Python - by Mark Lutz, O'Reilly Publications, 4th Edition, 2011. 6. Python in a nutshell - by Alex Martelli, Anna Ravenscroft, Steve Holden, O'Reilly Publications, 3rd Edition, 2017.	
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]	
1. NPTEL Lecture on Python for Data Science by Prof. Ragunathan Rengasamy, IIT Madras 2. NPTEL Lecture on Data Analytics with Python by Prof. A. Ramesh by IIT Roorkee	

Course Code	Course Name	L – T – P	Credits
AM505L	Computational Lab in Python and R	0-0-4	2

Course Objectives:

The course aims to introduce the basic concepts and usage of variables, expressions and practice the use of functions in Python Programming Language, highlight the practical aspects of data science and develop a broad view of data science implementations in academics and various industries. Further, it aims to build the fundamentals of statistical analysis using R.

Course Contents

Python Programming:

1. Write a Python program to print all pair combinations of elements from 2 tuples. Hint: Students may use list comprehension.
2. Write a Python program to concatenate consecutive elements in tuple. Hint: use map() and tuple methods for concatenation .
3. Write a function myReverse() which receives a string as an input and returns the reverse of the string.
4. Check if a given string is palindrome or not. Hint: do not use the C philosophy where we compare indices. Instead, copy the string as a new list, reverse the list using reverse(), join the list so that the reversed string is formed, using join(). Compare the new string and the old one.
5. Write a function to see if a given number is prime or not. Do not use any flag variables. Use a math module to find the square root, and its roof which will be fed in to range(). Hint: Just the return statements are enough. No need for flag variables. The loop has to run up to the roof of the square root of the number.
6. Create a nested dictionary. The roll number of a student maps to a dictionary. This inner dictionary will have name, age, and place as keys. Read details of at least three students. Hint: A sample output should look like the one given below: {11: {'name': 'Sachin', 'age': 18, 'place': 'Kochi'}, 12: {'name': 'Ammu', 'age': 19, 'place': 'Kannur'}, 13: {'name': 'jishad', 'age': 20, 'place': 'Calicut'}}
7. Enter a word. Create a dictionary with the letters of this word as keys, and the corresponding ASCII values as values. Hint: Students may use the ord() function. Further, this is a simple problem, if list comprehension is used.

8. Write a pandas program to select a name and score columns in rows 1,3,5,6 from the data frame consists of column values as index, name, score, attempts and qualify
9. Write a pandas program to implement line and box plots on the data frame student having the values as roll, name, exam1, exam2 and exam3.
10. Implement Multiple plots, Scatter plots with histogram and Bubble charts.

Statistical Analysis with R:

1. Write an R script to calculate the mean, median, standard deviation, and quantiles (0%, 25%, 50%, 75%, 100%) of the Petal.Length variable in the iris dataset. Present these values in a well-formatted table.
2. Using the mtcars dataset in R, create the following visualizations: A table summarizing the number of cars by the number of cylinders (cyl). A bar chart showing the frequency of different numbers of cylinders. A scatter plot of mpg (miles per gallon) versus hp (horsepower) with a regression line.
3. Write an R script to generate and visualize distributions: Binomial ($n=10$, $p=0.5$), Poisson ($\lambda=3$), Uniform (min=0, max=1), Normal (mean=0, sd=1). Create histograms for each distribution and superimpose the probability density functions (PDF) for the continuous distributions.
4. Using R, generate a large sample of 10,000 data points from uniform and normal distributions. Plot the cumulative distribution functions (CDF) and probability density functions (PDF) for both distributions. Compare and discuss the shapes of these functions.
5. Generate artificial data using a normal distribution (mean=5, sd=2) and a binomial distribution ($n=10$, $p=0.3$). Create density plots for both distributions and overlay the theoretical density functions. Additionally, plot the empirical and theoretical cumulative distribution functions (CDF).
6. Write an R program to generate a sample of 1000 data points from a normal distribution with a mean of 50 and a standard deviation of 10. Calculate the 95% confidence interval for the mean of the sample. Compare this with the population mean and discuss the results.
7. Simulate 1000 datasets, each consisting of 50 random samples from a normal distribution with mean 0 and standard deviation 1. For each dataset, calculate the 95% confidence interval for the mean. Plot the proportion of confidence intervals that contain the true population mean.
8. Write an R script to simulate data from an exponential distribution with rate parameter $\lambda = 0.5$. Generate 1000 samples, each of size 30, and compute the 90% confidence interval for the mean of each sample. Evaluate the coverage of these confidence intervals by determining the proportion that contains the true population mean.
9. Consider a dataset with two groups. Write an R program to perform a two-sample t-test to determine if there is a significant difference between the means of the two groups. Compute the p-value and interpret the results in terms of the null hypothesis and the critical region.
10. Given a dataset with two variables, write an R script to calculate the correlation between the variables, create a scatter plot, and fit a linear regression model using the lm function. Plot the regression line on the scatter plot and analyze the residuals.

Course Outcomes

After completing this course, the students develop the skill set to:

- CO1:** work on hands-on exercises and projects that involve solving data-related problems using Python
- CO2:** learn how to pre-process and clean raw data to make it suitable for analysis including handling missing data, dealing with outliers, data normalization, and feature scaling.
- CO3:** be able to analyze raw data and use different statistical methods on the data.
- CO4:** Perform linear regression models for data analysis
- CO5:** Perform and interpret different distribution using R

Text Books	
1. Mastering Python for Data Science by Samir Madhavan, PACKT Publishing, 2015. 2. Think Python by Allen Downey, O'Reilly Publications, 2nd Ed., 2016. 3. Python in a nutshell - by Alex Martelli, Anna Ravenscroft, Steve Holden, O'Reilly Publications, 3rd Edition, 2017. 4. The Book of R - A First Programming and Statistics - by Tilman M.Davies, Thomson Brooks/Cole. Library of Congress Cataloging-in-Publication Data, 4 th Ed., 2016. 5. An Introduction to Statistical Learning: with Applications in R by Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, Springer, 1st Ed., 2017.	
Reference Books	
1. Python for Data Analysis: Data Wrangling with Pandas, NumPy, and IPython - by Wes McKinney, O'Reilly Media, Inc., 2nd edition, 2017. 2. Programming Python - by Mark Lutz, O'Reilly Publications, 4th Edition, 2011. 3. R Programming for Beginners by Steven Keller, CreateSpace Independent Publishing Platform 2016. 4. Learning R Programming by Kun Ren, Packt Publishing, 2016. 3.	
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]	
1. NPTEL Lecture on Python for Data Science by Prof. Ragunathan Rengasamy, IIT Madras 2. NPTEL Lecture on Data Analytics with Python by Prof. A. Ramesh by IIT Roorkee 3. https://web.itu.edu.tr/~tokarem/The_Book_of_R.pdf 4. https://online-learning.harvard.edu/subject/r	

SECOND SEMESTER

Course Code	Course Name	L – T – P	Credits
AM521	Artificial Intelligence & Machine Learning	3-0-2	4
Course Objectives: This course aims to understand the foundational principles of machine learning, including well-posed learning problems, inductive bias, and hypothesis evaluation. It also explores classical learning paradigms such as supervised, unsupervised, and reinforcement learning. In this course, student will implement and evaluate core machine learning algorithms including decision trees, neural networks, SVMs, and k-NN. Further, the course introduces probabilistic models such as Naïve Bayes and Bayesian networks for classification and prediction under uncertainty with advanced learning strategies like genetic algorithms, reinforcement learning, and analytical learning.			

Course Contents
Unit – 1: Foundations of AI and Machine Learning Introduction to AI - Intelligent Agents, Problem-Solving Agents, Search space, Well-posed learning problems, Concept learning (Find-S, Candidate Elimination), Inductive bias, Overfitting, Generalization Unit – 2: Supervised Learning Decision Trees, k-Nearest Neighbors (k-NN), Naïve Bayes, Linear and Polynomial Regression Support Vector Machines (SVMs), Artificial Neural Networks, Regularization algorithms, Lasso, Ridge Unit – 3: Unsupervised Learning Partition-based Clustering: K-Means Algorithm, Hierarchical Clustering: Agglomerative and Divisive, Spectral Clustering: Laplacian Matrix and similarity-based clustering, Density-Based Clustering: DBSCAN, Model-based Clustering: Gaussian Mixture Models (GMMs) and Expectation Maximization (EM) Algorithm, Dimensionality Reduction: PCA, t-SNE, Anomaly Detection Unit – 4: Probabilistic and Ensemble Methods Bayesian Learning: Bayes theorem, EM Algorithm Bagging, Boosting, Random Forests Evaluation: Cross-validation, ROC, AUC, F1 Unit – 5: Reinforcement Learning and Evolutionary Learning Basics of Reinforcement Learning, Genetic Algorithms, Model interpretability and ethical considerations in ML Unit – 6: Practical Implementation using Python Python libraries for ML: NumPy, Pandas, scikit-learn, matplotlib, seaborn, Implementation of: Regression Algorithms, Classification Algorithms, Clustering Algorithms Data preprocessing and feature scaling, Performance evaluation using real-world datasets
Course Outcomes
After completing this course, the students develop the skill set to: CO1: formulate AI/ML problems using state space, learning frameworks, and data representations. CO2: Implement and evaluate supervised and unsupervised learning algorithms. CO3: apply AI techniques to solve problems of game playing, theorem proving, and machine learning. CO4: apply probabilistic models and ensemble methods for prediction under uncertainty. CO5: understand the concepts of state space representation, exhaustive search, heuristic search together with the time and space complexities
Text Books
1. Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Norvig, Pearson Education/ Prentice Hall of India, 3rd Ed., 2010. 2. Artificial Intelligence by E. Rich and K. Knight, 3rd Ed., McGraw Hill, 2009. 3. Essentials of Artificial Intelligence by M. Ginsberg, Elsevier Science, 2012. 4. Machine Learning: A Probabilistic Perspective - Murphy, K. P., MIT Press, 2012.
Reference Books
1. Foundations of Artificial Intelligence and Expert Systems by Janakiraman, K. Sarukesi, Macmillan Series in Computer Science, 2005. 2. Expert Systems: Principles and Programming by Joseph C. Giarratano, Gary D. Riley, Course Technology Inc., 4th Edition, 2015. 3. Artificial Intelligence with Python by Prateek Joshi, Packt Publishing, 2017. 4. Introduction to Artificial Intelligence and Expert Systems by W. Patterson, Prentice Hall of India, 2003.

5. Artificial Intelligence: A New Synthesis by Nils J. Nilsson, Harcourt Asia Pvt. Ltd., 2000.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Artificial Intelligence by Prof. P. Dasgupta, IIT Kharagpur
2. NPTEL Lecture on An Introduction to Artificial Intelligence by Prof. Mausam, IIT Delhi

Course Code	Course Name	L – T – P	Credits
AM522	Big Data Analysis and Algorithms	3-0-0	3

Course Objectives:

The purpose of the course is to introduce Big Data characteristics, sources, and the importance of Big Data in various domains, explore the Big Data ecosystem, including tools and technologies such as Hadoop, and NoSQL databases. The aim is to learn methods and techniques for collecting, storing, and managing large datasets and understand data storage options, including distributed file systems, cloud storage, and databases optimized for Big Data.

Course Contents

Unit – 1: Introduction to Big Data and Data Models

Types of Digital Data, Characteristics of Data, Basics of DBMS, Data Models, Evolution of data, data streams, structured & unstructured data, database models, graph data, normalizations, Introduction to Big Data, Business Intelligence vs Big Data, Data Warehouse and Hadoop Environment, Challenges of Conventional Systems, Intelligent data analysis, Nature of Data, Analytic Processes and Tools, Analysis vs Reporting

Unit – 2: Big Data Analytics

Data Analytics, Classification of Data Analytics, Data Science, Terminologies in Big Data, ACID, BASE models, CAP Theorem, Distributed Models, Single Server, Sharding, Master-Slave Replication, Peer to Peer Replication. Key-Value Databases: Comparison of Relational and Key Value Store, Features. Document Databases: Comparison of Relational and Document Database, Advantages and Disadvantages, Features. Column Family Stores- Comparison of Relational and Column Family, Advantages and Disadvantages, Data Modeling: Data Model-Key-Value Data Model- Columnar Data Model, Graph Based Data Model Graph Data Model, From Data Analysis to Database–The Entity-Relationship Model - Implementation in the Relational Model-Implementation in the Graph Model – Enterprise-wide Data Architecture – Formula for Database Design

Unit – 3: NoSQL Databases and Hadoop Ecosystem

Types of Databases, Advantages, NewSQL, SQL vs NoSQL vs NewSQL, Introduction to Hadoop: Features, advantages, versions, overview of Hadoop Ecosystems, Hadoop vs SQL, RDBMS vs Hadoop, Components, Architecture, HDFS, MapReduce: Mapper, Reducer, Combiner, Partitioner, Searching, Sorting, Compression, Hadoop 2 (YARN), architecture, interacting with Hadoop Eco systems

Unit – 4: Big Data Tools

Mongo DB: Introduction, features, data types, Mongo DB query language, CRUD operations, arrays, functions: count, sort, limit, skip, aggregate, mapreduce, cursors, indexes, mongo import, mongo export

Unit – 5: Algorithms for Massive Data Sets

Algorithms for SISD, SIMD environments, Linked Big Data Analysis, Graph Computing and Network Science, Big Data Visualization, Big Data Mobile Applications, case studies of finding similar items, mining data streams, page rank algorithms, link analysis

Course Outcomes

After completing this course, the students develop the skill set to:

CO1: understand the challenges of scaling Big Data solutions and learn techniques for optimizing performance.

CO2: develop skills to visualize and communicate findings from Big Data analytics tools

CO3: understand techniques for processing large datasets using tools such as MapReduce, and other parallel processing frameworks

CO4: explore new tools, frameworks, and technologies shaping the future of Big Data.

CO5: apply Big Data concepts and techniques through hands-on projects and real-world case studies.

Text Books

1. Big Data Fundamentals: Concepts, Drivers & Techniques by Thomas Erl, Wajid Khattak, Paul Buhler, Prentice Hall, 2016.
2. Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006
3. Introduction to Algorithms by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein, MIT Press, 3rd Ed., 2009.
4. Big Data and Analytics by Seema Acharya, Subhashini Chellappan, Wiley, 2nd Ed., 2019.

Reference Books

1. Understanding Big Data: Analytics for Enterprise Class Hadoop and Streaming Data (McGraw-Hill Education, 2011) by Paul Zikopoulos and Chris Eaton
2. Mining of Massive Datasets by Jure Leskovec, Anand Rajaraman, Jeffrey David Ullman, DREAMTECH Press, 2nd Ed., 2016.
3. Big Data Analytics: Methods and Applications by Saumyadipta Pyne, B.L.S. Prakasa Rao, S.B. Rao, Springer, 1st Ed., 2016.
4. Big Data, Big Analytics: Emerging Business Intelligence and Analytic Trends for Today's Businesses by Michele Chambers, Michael Minelli, Ambiga Dhiraj, Wiley, 2013.
5. Machine Learning for Big Data: Hands-On for Developers and Technical Professionals by Jason Bell, Wiley, 2014.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. Article on Why Big Data is the New Competitive Advantage
2. NPTEL Lecture on Algorithms for Big Data by Prof. John Augustine, IIT Madras

THIRD SEMESTER

Course Code	Course Name	L – T – P	Credits
AM531	Time Series Analysis & Forecasting Methods	3-0-2	4

Course Objectives:

The objectives of this course are to introduce the fundamental concepts of time series data and the decomposition of its components (trend, seasonality, cyclical, and irregularity). It develops proficiency in mathematical modeling of time series using deterministic and stochastic approaches. The course covers key concepts such as stationarity, autoregressive and moving average models, and advanced ARIMA techniques. This course will equip students with exponential smoothing techniques and Box-Jenkins modeling methodology and enable the understanding of spectral analysis using Fourier techniques for identifying cyclic patterns. It also introduces methods for forecasting using linear and nonlinear time series models, including multivariate approaches and state-space models like the Kalman Filter and also imparting skills to assess stationarity and causality using statistical tests such as ADF, KPSS, and Granger Causality.

Course Contents

Unit- 1: Introduction to Time Series Analysis

Review of Time Series Analysis. Growth models: Modified Exponential Curve, Gompertz curve, Logistic curve and their Fitting; Measurement of cyclical component: Harmonic analysis, auto regression series: Markoff and Yule's series, Periodogram and correlogram analysis, measurement of irregular component: variate difference method. Difference Equations, Lag Operators, pth-Order Difference Equations. White Noise, Expectations, Stationarity, and Ergodicity. Models of Nonstationary Time Series: Why Linear Time Trends and Unit Roots? Random Walk Models, Brownian Motion, Geometric Brownian Motion. Canonical Correlation Time Series Models of Heteroscedasticity: ARCH and GARCH model, Granger Causality Test ADF, KPSS Test for Stationary

Unit- 2: Exponential smoothing methods

Trend adjusted exponential smoothing, double and triple exponential smoothing, Holt and Winters smoothing, chow's adaptive control methods, brown's one parameter adaptive method:

Unit- 3: Detailed study of the stationary processes

Linear Models, Autoregressive Processes, Moving Average (MA), Auto Regressive (AR), ARMA and AR Integrated MA(ARIMA)models - forecasting with ARIMA models.

Unit- 4: Box-Jenkins models

Discussion (without proof) of estimation of mean, auto covariance and auto-correlation functions under large sample theory. Choice of AR and MA periods. Estimation of ARIMA model parameters.

Unit- 5: Spectral Analysis

Spectral analysis of weakly stationary process. Periodogram and correlogram analyses. Computations based on Fourier transform.

Unit - 6: Forecasting

Principles of Forecasting, Forecasts with Gaussian Processes, Wold's Decomposition and the Box-Jenkins Modelling Philosophy, Parameter Estimation, Maximum Likelihood Estimation. Vector Auto regressions; Bivariate Granger Causality Tests. Understanding Kalman Filter

Course Outcomes			
After successful completion of the course, students will be able to: CO1: Explain the components of a time series and apply different growth and cyclical models such as Gompertz, logistic, and harmonic analysis. CO2: Analyze non-stationary time series using Random Walk, Brownian Motion, and heteroscedasticity models like ARCH and GARCH. CO3: Develop and apply stationary models like AR, MA, ARMA, and ARIMA for time series forecasting. CO4: Perform spectral analysis and understand the role of periodogram and correlogram in identifying periodic components. CO5: Conduct time series forecasting using Gaussian processes, Maximum Likelihood Estimation, and Vector Autoregressions; implement and interpret results from the Kalman Filter.			
Text Books			
1. Time Series Analysis by James D. Hamilton, Princeton University Press, 2012. 2. Time Series Analysis and Its Applications: With R Examples by Robert H. Shumway, David S. Stoffer, Springer Texts in Statistics, 2017. 3. Understanding the Kalman Filter by Richard J. Meinhold, Nozer D. Singpurwalla, The American Statistician Vol. 37, No. 2, pp. 123-127, (May, 1983). 4. The Statistical Analysis of Time Series by Anderson, T.W., Wiley, 1971. 5. Forecasting and Time Series Analysis by Montgomery, D.C. and Johnson, L.A., McGraw Hill, 1977.			
Reference Books			
1. Introduction to Statistical Time Series by Fuller, W.A., John Wiley, 2nd Ed., 1995. 2. Forecasting Econometric Time Series by N.Y. Granger, C.W.J. and Newbold, Academic Press, 3rd Ed., 1984. 3. Spectral Analysis and Time Series by Priestley, M.B., Griffin, London, 1981. 4. Time Series Analysis by Kendall, S.M. and Ord, J.K., 3rd Ed., Edward, 1981. 5. The Advanced Theory of Statistics by Kendall, M.G. and Stuart, A., Vol.3, Charles Griffin, London, 1966. 6. The Spectral Analysis of Time Series by Koopmans, L.H., Academic Press, 1974.			
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]			
1. Coursera Course on Practical Time Series Analysis 2. NPTEL Lecture on Applied Time-Series Analysis by Dr. Arun K.Tangirala, IIT Madras			

Course Code	Course Name	L – T – P	Credits
AM532	Deep Learning	3-0-0	3
Course Objectives: This course provides a comprehensive understanding of the architecture, training, and optimization of deep neural networks. It enables students to apply deep learning models to tasks involving computer vision, natural language processing, and sequential data. Key topics include optimization techniques, regularization strategies, and approaches to improve generalization in deep models. The course explores advanced architectures such as Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs),			

Generative Adversarial Networks (GANs), and Transformers. Students will also engage with recent research trends and developments in deep learning through hands-on implementation and experimentation.
Course Contents
Unit – 1: Introduction to Neural Networks Artificial Neural Networks-1– Introduction, neural network representation, appropriate problems for neural network learning, perceptions, multilayer networks and the back-propagation algorithm. Artificial Neural Networks-2- Remarks on the Back-Propagation algorithm, An illustrative example: face recognition, advanced topics in artificial neural networks. Unit – 2: Evaluation of Hypotheses and Model Selection Evaluation Hypotheses – Motivation, estimation hypothesis accuracy, basics of sampling theory, a general approach for deriving confidence intervals, difference in error of two hypotheses, comparing learning algorithms. Unit – 3: Convolutional Neural Networks (CNNs) CNN layers: convolution, pooling, padding, Image classification, object detection basics, Transfer learning and fine-tuning for domain-specific applications, Activation functions and Normalization techniques Unit – 4: Recurrent Neural Networks (RNNs) RNNs, LSTMs, GRUs, Applications to sequential data (e.g., text, speech and time series), Vanishing gradient problem & solutions Unit – 5: Generative Models Architecture, training, and applications of Autoencoders, Generative Adversarial Networks (GANs): basics and applications, Applications in synthetic image generation, anomaly detection and data augmentation
Course Outcomes
After completing this course, the students develop the skill set to: CO1: Understand the foundational concepts of neural networks, including perceptron, activation functions, loss functions, and backpropagation. CO2: Design and implement deep learning models such as CNNs, RNNs, LSTMs, and Transformers for solving real-world problems in computer vision, NLP, and time-series analysis. CO3: Analyze and optimize deep learning architectures using regularization techniques, advanced optimizers, and performance evaluation metrics. CO4: Apply deep learning frameworks (TensorFlow/PyTorch/Keras) to develop, train, and deploy models for real-time applications. CO5: awareness of current trends, applications, and ethical considerations in deep learning across academia and industry.
Text Books
1. Deep Learning by Aaron Courville, Ian Goodfellow, Yoshua Bengio, MIT Press, 2016. 2. Machine Learning by Tom M. Mitchell, McGraw Hill Education, 1st Ed., 2017. 3. Deep Learning with Python by F. Chollet, 2nd Ed., Manning Publications, 2021. 4. Natural Language Processing with Transformers by L. Tunstall, L. Werra and T. Wolf, O'Reilly, 2022.
Reference Books

1. Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow by A. Géron, 3rd ed., O'Reilly, 2022. 2. Computer Vision: Algorithms and Applications by R. Szeliski, 2nd ed., Springer, 2022. 3. The Elements of Statistical Learning: Data Mining, Inference, and Prediction by Hastie, Tibshirani, Friedman, 2nd Ed., Springer, 2017. 4. Speech and Language Processing by D. Jurafsky, and J.H. Martin, 3rd ed., Pearson, 2023.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
NPTEL Lecture on Introduction to Machine Learning by Prof. S. Sarkar, IIT Kharagpur

Course Code	Course Name	L – T – P	Credits
AM523	Optimization Techniques	3-0-0	3

Course Objectives:

To study the model formulation and discussion of documented real-world applications. Study of mathematical programming algorithms. Apply the mathematical results and numerical techniques of optimization theory to concrete Engineering problems.

Course Contents

Unit – 1: Constrained and Unconstrained Optimization

Constrained optimization (Penalty methods, Lagrange multipliers, Karush-Kuhn-Tucker conditions). Unconstrained optimization using calculus (Taylor's theorem, convex functions, coercive functions), Unconstrained optimization via iterative methods (Newton's method, gradient/conjugate gradient methods, quasi-newton methods)

Unit – 2: Linear Programming

Introduction to Linear Programming Problem (LPP), Graphical Method, Simplex Method, Dual Simplex Method, Two Phase Method, Degeneracy, Alternative Optima, Graphical Sensitivity Analysis, Sub-Optimization; LP-Duality and Sensitivity Analysis: Definition of Dual, Primal-Dual Relationships, Dual Simplex Sensitivity or Post Optimal Analysis, Revised Simplex Method, Bounded-Variable Algorithm, Duality, Parametric programming

Unit – 3: Integer Programming

Formulation and Applications-Cutting Plane Algorithm-Branch and Bound Method.

Unit – 4: Deterministic Inventory models

EOQ models, EOQ with price breaks, Multi-Item EOQ with storage limitation.

Unit – 5: Queuing Systems

Pure birth and Pure death models, generalized Poisson queuing model, single server models.

Unit – 6: Numerical methods for optimization

Minimization and maximization of convex functions- Local & Global optimum- Convergence-Speed of convergence. Nelder Mead's Simplex search method.

Course Outcomes

After completing this course, the students develop the skill set to:

CO1: become a mathematical translation of the verbal formulation of an optimization problem;

CO2: discovery, study and solve optimization problems;

CO3: Investigate, study, develop, organize and promote innovative solutions for various applications CO4: be able to formulate optimization problems with constraints and without constraints CO5: have an understanding of transportation and assignment problems and various optimization techniques
Text Books
1. Operations Research- An Introduction by Hamdy A.Taha, Pearson, 10th Ed., 2019. 2. Numerical Optimization by J. Nocedal, S. Wright, Springer, 2nd Ed., 2006. 3. Numerical Methods and Optimization by Hari Arora, S.K. Kataria & Sons, 2013. 4. An Introduction to Optimization, 4th Edition, by Edwin K. P. Chong, Stanislaw H. Zak, John Wiley & Sons, 2008 5. Practical Optimization: Algorithms and Engineering Applications by Andreas Antoniou, Wu-Sheng Lu, Springer, 2007.
Reference Books
1. Optimization Techniques, by L. R. Foulds, Springer, UTM, 1981. 2. Introduction to Linear Optimization by D. Bertsimas and J. N. Tsitsiklis, Athena Scientific, 1997. 3. Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer, 2016. 4. Engineering Optimization: Theory and Practice by S.S. Rao, Wiley, 5th Ed., 2019. 5. Introduction to Optimization by E.M.L. Beale, E. M. Beale, Wiley, 1998. 6. Nonlinear Programming by D. P. Bertsekas, Athena Scientific, 3rd Ed., 2016. 7. An Introduction to Optimization by Edwin K. P. Chong, Stanislaw H. Zak, Wiley, 4th Ed., 2013.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Numerical Optimization by Dr. Shirish K. Shevade, IISc Bangalore 2. NPTEL Lecture on Constrained and Unconstrained Optimization by Dr. Debjani Chakraborty, Prof. A. Goswami, IIT Kharagpur

Course Code	Course Name	L – T – P	Credits
AM524	Regression Analysis and Predictive Modelling	3-0-0	3
Course Objectives: This course aims to develop an understanding of regression analysis and model building, to provide the ability to develop relationship between variables, to introduce the investigating tools for possible diagnostics in regression techniques and to formulate feasible solution using regression model for real-life problems.			
Course Contents			
Unit- 1: Simple Regression Analysis Introduction to Linear and Nonlinear Model, Ordinary Least Square Method, Simple Linear Regression Model, using Simple Regression to Describe a Linear Relationship, Fitting a Linear Trend to Time Series Data, Validating Simple Regression Model using t, F and p-Test, Developing Confidence Interval. Precautions in Interpreting Regression Result			
Unit - 2: Multiple Regression Analysis Concept of Multiple Regression Model to Describe a Linear Relationship, Assessing the Fit of the Regression Line, Inferences from Multiple Regression Analysis, Problem of Overfitting of a Model, Comparing Two Regression Model, Prediction with Multiple Regression Equation, Penalized Likelihood Regression			
Unit - 3: Fitting Curves and Model Adequacy Checking Introduction, Fitting Curvilinear Relationship, Residual Analysis, PRESS Statistics, Detection and Treatment of Outliers, Lack of Fit of the Regression Model, Test of Lack of Fit, Problem of Autocorrelation and Heteroscedasticity. Estimation of Pure Errors from Near Neighbors.			
Unit - 4: Transformation techniques and Multicollinearity Introduction, Variance Stabilizing Transformations, Transformations to Linearize The Model, Box-Cox Methods, Transformations on The Regressor's Variables, Generalized and Weighted Least Squares, Some Practical Applications; Multicollinearity: Sources of Multicollinearity, Effects of Multicollinearity. Multicollinearity Diagnostics: Examination of Correlation Matrix, Variance Inflation Factors (VIF), Eigen System Analysis of $X^T X$. Methods of Dealing with Multicollinearity: Collecting Additional Data, Model Re-Specification, and Ridge Regression			
Unit – 5: Generalized Linear Models Generalized Linear Model: Link Functions and Linear Predictors, Parameter Estimation and Inference in the GLM, Prediction and Estimation with the GLM, Residual Analysis, and Concept of Over Dispersion, Generalised Additive Models.			
Unit – 6: Model building and Nonlinear Regression Variable Selection with LASSO and Elastic Net, Model Building, Model Misspecification. Model Validation Techniques: Analysis of Model Coefficients, and Predicted Values, Data Splitting Method. Nonlinear Regression Model, Nonlinear Least Squares, Spline Regression, Transformation to Linear Model, Parameter Estimation in Nonlinear System, Statistical Inference in Nonlinear Regression, Gaussian Process Regression, Gaussian Process Optimization			
Course Outcomes			

After completing this course, the students develop the skill set to:

- CO1:** develop in-depth understanding of the linear and nonlinear regression model.
- CO2:** demonstrate the knowledge of regression modeling and model selection techniques.
- CO3:** examine the relationships between dependent and independent variables.
- CO4:** estimate the parameters and fit a model and validate the model using hypothesis testing and confidence interval approach.
- CO5:** understand the generalizations of the linear model to binary and count data.

Text Books

1. Introduction to Statistical Learning with applications in R by Gareth James, Daniela Witten , Trevor Hastie, Robert Tibshirani., Springer, 2013.
2. Regression and Other Stories by Andrew Gelman, Jennifer Hill, Aki Vehtari, Cambridge University Press, 2020.
3. Introduction to Linear Regression Analysis by Douglas C. Montgomery, Elizabeth A. Peck, G. Geoffrey Vining, Wiley India Pvt. Ltd., 3rd Ed., 2016.
4. Applied Regression Analysis by Norman R. Draper, Harry Smith, WILEY India Pvt. Ltd. New Delhi, 3rd Ed., 2015.
5. Gaussian Process for Machine Learning by Carl Edward Rasmussen, Christopher K. I. Williams, MIT Press 2005.

Reference Books

1. Applied Multivariate Statistical Analysis by Johnson, R A., Wichern, D. W., PHI learning Pvt., Ltd., 6th Ed., 2013.
2. Applied Regression Modelling by Iain Pardoe, John Wiley and Sons, Inc, 2012.
3. Applied Linear Regression Models by Michael H. Kutner, Chris Nachtsheim, John Neter, McGraw, 2004.
4. Regression Analysis by Example by Samprit Chatterjee, Ali S. Hadi, Wiley, 5th Ed., 2013.
5. The Elements of Statistical Learning: Data Mining, Inference, and Prediction by Trevor Hastie, Robert Tibshirani, Jerome Friedman, Springer, 2nd Ed., 2009.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Predictive Analytics: Regression and Classification by Prof. Sourish Das, IIT Madras

Course Code	Course Name	L – T – P	Credits
AM525	Measure Theory and Multivariate Calculus	3-0-0	3
Course Objectives: This course aims to introduce the foundational concepts of measure theory including σ -algebras, measurable functions, and Lebesgue integration. It also provides a rigorous treatment of multivariate calculus concepts such as multiple integrals, Jacobians, and transformation of variables. The course aims to equip students with a strong mathematical foundation for further studies in probability theory, functional analysis, and machine learning, while also enabling them to apply integration techniques over manifolds and regions in higher dimensions.			
Course Contents			
Unit 1: Basics of Measure Theory σ -algebras, measurable spaces and functions; Borel sets; outer measure and Lebesgue measure on $\mathbb{R}$; measurable sets and their properties.			
Unit 2: Lebesgue Integration Lebesgue integral of non-negative functions; convergence theorems (Monotone Convergence, Fatou's Lemma, Dominated Convergence); comparison with Riemann integral; functions of bounded variation; absolute continuity.			
Unit 3: Product Measures and Fubini's Theorem Product σ -algebras and product measures; Tonelli's and Fubini's theorems; applications to double and multiple integrals; integration in polar, cylindrical, and spherical coordinates.			
Unit 4: Multivariate Calculus – Differentiation Functions of several variables; gradients, directional derivatives, Hessians; differentiability and Taylor's theorem in $\mathbb{R}^n$; Implicit and Inverse Function Theorems.			
Unit 5: Multivariate Calculus – Integration and Change of Variables Multiple integrals; Jacobian determinant and change of variables in integrals; line integrals and surface integrals; Green's, Gauss's, and Stokes' Theorems.			
Course Outcomes			
After completing this course, the students develop the skill set to: CO1: Understand the rigorous foundations of measure theory and Lebesgue integration. CO2: Apply measure-theoretic concepts in analysis and probability theory. CO3: Perform multivariable integration with changes of coordinates and understand Jacobians. CO4: Use differential calculus in higher dimensions, including implicit mappings and optimization. CO5: Connect multivariate calculus concepts with geometric intuition via line, surface, and volume integrals.			
Text Books			
1. Real Analysis by H.L. Royden, and P.M. Fitzpatrick, 4th ed., Pearson, 2010. 2. The Elements of Integration and Lebesgue Measure by R.G. Bartle, Wiley, 1995. 3. Real Analysis: Modern Techniques and Their Applications by G.B. Folland, 2nd ed., Wiley, 1999. 4. Calculus, Vol. II: Multi-Variable Calculus and Linear Algebra by T.M. Apostol, 2nd ed., Wiley, 1969.			

5. A course in multivariable calculus and analysis by S.R. Ghorpade and B.V. Limaye, Springer, 2010.

Reference Books

1. Principles of Mathematical Analysis by W. Rudin, 3rd ed., McGraw-Hill, 1976.
2. Measure theory and probability theory by Krishna B. Athreya and S. Lahiri, Springer, 2006.
3. Introduction to Probability and Measure by K. R. Parthasarathy, Hindustan, 2005.
4. Calculus on Manifolds by M. Spivak, Westview Press, 1965.
5. Functions of several variables by W. Fleming, 2nd Ed., Springer, 1977.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Measure Theory by Prof. E.K. Narayanan, IISc
2. NPTEL Lecture on Multivariate Calculus by Dr. Sanjeev Kumar, Dr. S.K. Gupta, IIT Roorkee

Course Code	Course Name	L – T – P	Credits
AM526	Functional Analysis	3-0-0	3

Course Objectives:

This course aims to introduce the foundational principles of normed and inner product spaces and develop understanding of linear operators, dual spaces, and the role of compactness. It emphasizes the study of important theorems in Functional Analysis such as Hahn-Banach, Open Mapping, and Uniform Boundedness. Further, the course explores various concepts of functional analysis in the context of differential equations, optimization, and quantum mechanics.

Course Contents

Unit 1: Normed Linear Spaces and Banach Spaces

Normed spaces, examples; convergence, completeness, Banach spaces; subspaces, quotient spaces, and linear operators; bounded and continuous operators; dual space and norm.

Unit 2: Inner Product Spaces and Hilbert Spaces

Inner product spaces; orthogonality, orthonormal sets, Gram-Schmidt process; Hilbert spaces; projection theorem, Riesz representation theorem.

Unit 3: Fundamental Theorems of Functional Analysis

Hahn-Banach Theorem (extension and separation forms); Open Mapping Theorem; Closed Graph Theorem; Uniform Boundedness Principle.

Unit 4: Compact Operators and Applications

Compact operators on normed and Hilbert spaces; spectral theory for compact self-adjoint operators; applications in differential and integral equations.

Unit 5: Applications Topics

Weak convergence; reflexivity; Banach-Alaoglu theorem; applications in PDEs, Fourier series, and applications in quantum mechanics.

Course Outcomes
After completing this course, the students develop the skill set to: CO1: Understand the structure of normed and inner product spaces and key properties. CO2: Apply fundamental theorems of functional analysis in theoretical and applied settings. CO3: Analyze the behavior of linear operators and understand their spectral properties. CO4: Use concepts of weak convergence, compactness, and duality in mathematical modeling. CO5: Connect abstract concepts in functional analysis with real-world applications like PDEs and quantum theory
Text Books
1. Introductory Functional Analysis with Applications by E. Kreyszig, Wiley, 1978. 2. A Course in Functional Analysis by J. B. Conway, Second Edition, Springer, 1990. 3. Functional Analysis by P. Lax, Wiley-Interscience, 2002. 4. Functional Analysis by G. Bachman and L. Narici, Dover, 2002. 5. Functional Analysis by S. Kesavan, 2nd Ed., Springer, 2023.
Reference Books
1. Functional Analysis by Rudin, W., McGraw-Hill, 1991. 2. Functional Analysis by K. Yosida, 6th ed., Springer-Verlag, 1980. 3. Introduction to Topology and Modern Analysis by G.F. Simmons, 1st ed., McGraw-Hill, 1963. 4. Introduction to Functional Analysis by A.E. Taylor and D.C. Lay, 2nd Ed., Wiley, 1980 5. Functional Analysis by M. Reed and B. Simon, Academic Press, 1980.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Functional Analysis by Prof. S Kesavan, IIMSC

Course Code	Course Name	L – T – P	Credits
AM533	Multivariate Data Analysis	3-0-0	3

Course Objectives:

To understand the fundamental concepts of Multivariate Data Analysis / Multivariate Statistical Analysis, become conversant with various methods and techniques used in summarization and analysis of multivariate data, to prepare for investigation of multivariate data and examine the possible diagnostics in multivariate methods, to formulate real time problem in a form of multivariate model, to Develop feasible solution of real-life problems, using multivariate methods and techniques and to conduct research using multivariate data analysis techniques.

Course Contents

Unit – 1: Introduction to Multivariate Data Analysis

Multivariate data and their diagrammatic representation. Exploratory multivariate data analysis, sample mean vector, sample dispersion matrix, sample correlation matrix, graphical representation, means, variances, co-variances, correlations of linear transforms, six step approach to multivariate model building. Introduction to multivariate linear regression, logistic regression, principal component analysis, factor analysis, cluster analysis, canonical analysis and canonical variables, structured equation modeling (SEM).

Unit - 2: Multivariate Normal Distribution (MND)

Introduction to multivariate normal distribution, probability density function and moment generating function of multivariate normal distribution, singular and nonsingular normal distributions, distribution of linear and quadratic form of normal variables, marginal and conditional distributions. Random sampling from multivariate normal distributions. Goodness of fit of multivariate normal distribution. Wishart matrix-its distribution and properties.

Unit - 3: Multivariate Linear Model and Analysis of Variance and Covariance

Maximum likelihood estimation of parameters, tests of linear hypothesis, distribution of partial and multiple correlation coefficients and regression coefficients. Multivariate linear regression, multivariate analysis of variance of one- and two-way classification data (only LR test). Multivariate analysis of covariance. Hotelling T^2 and Mahalanobis D^2 applications in testing and confidence set construction.

Unit – 4: Multiple Discriminant Analysis and Logistic Regression

Multiple Discriminant Analysis: a two-group discriminant analysis, a three-group discriminant analysis, the decision process of discriminant analysis (objective, research design, assumptions, estimation of the model, assessing overall fit of a model, interpretation of the results, validation of the results).

Logistic Regression model and analysis: regression with a binary dependent variable, representation of the binary dependent variable, estimating the logistic regression model, assessing the goodness of fit of the estimation model, testing for significance of the coefficients, interpreting the coefficients.

Unit – 5: Principal Components and common Factor Analysis

Population and sample principal components, their uses and applications, large sample inferences, graphical representation of principal components, Biplots, the orthogonal factor model, dimension reduction, estimation of factor loading and factor scores, interpretation of factor analysis.

Unit – 6: Cluster Analysis, Scaling and Structural Equation Modelling (SEM)

Concepts of cluster analysis and multidimensional scaling, similarity measures, hierarchical clustering methods, Ward's hierarchical clustering method's, nonhierarchical clustering methods, K-means methods. Clustering based on statistical models, multidimensional scaling and correspondence analysis, perceptual

mapping; Concept of structural equation modeling, Confirmatory factor analysis, canonical correlation analysis, conjoint analysis.
Course Outcomes
After completing this course, the students develop the skill set to: CO1: develop an in-depth understanding of the Multivariate models, methods and techniques. CO2: demonstrate the knowledge and skill of multivariate normal distributions, related probability distributions and their applications. CO3: examine the relationships between dependent and independent variables of multivariate models, estimate the parameters and fit a model. CO4: investigate the events of clustering and multidimensional scaling presence in sample data. CO5: conduct the application of Structural Equation Modeling (SEM) to real-time observations
Text Books
1. Applied Multivariate Statistical Analysis by Hardy W.K. and Simor L., 4th Edition, Springer-Verlag, 2015. 2. Applied Multivariate Statistical Analysis by Richard A. Johnson and Dean W. Wichern, Prentice hall India, 7th Edition, 2019. 3. An Introduction to Multivariate Statistical Analysis by Anderson T.W., Wiley, 3rd Edition, 2009. 4. Multivariate Analysis by Kshirsagar, A. M., Marcel Dekkar, 2006.
Reference Books
1. Applied Multivariate Statistical Analysis by Johnson, R A., Wichern, D. W., PHI learning Pvt., Ltd., 6th Ed., 2013. 2. Multivariate Statistics and Probability by Rao, C. R. and Rao, M. M., Elsevier & Academic Press, 2014. 3. Multivariate Analysis and its Applications by Bhuyan, K. C., New Central book Agency Pvt. Ltd., 2005. 4. Applied Linear Regression by Weisberg S., 4th Edition, Wiley, 2013. 5. Advanced Multivariate Statistical Analysis with Matrices by Kollo T., and Rosen D. Von, Springer, New York, 2005.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Multivariate Data Analysis by Dr. Sharmishtha Mitra, Dr. Amit Mitra, IIT Kanpur

Course Code	Course Name	L – T – P	Credits
AM534	Digital Image Processing	3-0-0	3
Course Objectives: The course aims to provide a solid foundation in understanding how digital images are represented and stored in computer systems including concepts such as pixel values, color models, and spatial and frequency domains.			
Course Contents			
Unit – 1: Introduction to Digital Image Processing Digital Image Processing: Introduction - The Origins of Digital Image Processing - Examples of Fields that Use Digital Image Processing - Fundamental Steps in Digital Image Processing - Components of an Image Processing System - Digital Image Fundamentals: Elements of Visual Perception - Light and the Electromagnetic Spectrum. Image Sensing and Acquisition - Image Sampling and Quantization - Some Basic Relationships Between Pixels - An Introduction to the Mathematical Tools Used in Digital Image Processing.			
Unit – 2: Fourier Transforms Filtering in the Frequency Domain: Background - Preliminary Concepts - Sampling and the Fourier Transform of Sampled Functions - The Discrete Fourier Transform of One Variable - Extensions to Functions of Two Variables - Some Properties of the 2-D DFT and IDFT - The Basics of Filtering in the Frequency Domain - Image Smoothing Using Lowpass Frequency Domain Filters - Image Sharpening Using High Pass Filters - Selective Filtering - The Fast Fourier Transform.			
Unit – 3: Image Restoration Image Restoration and Reconstruction: Noise Models - Restoration in the Presence of Noise Only Spatial Filtering - Periodic Noise Reduction Using Frequency Domain Filtering - Linear, Position-Invariant Degradations - Estimating the Degradation Function - Inverse Filtering - Minimum Mean Square Error (Wiener) Filtering - Constrained Least Squares Filtering - Geometric Mean Filter.			
Unit – 4: Image Transformation Wavelet and Other Image Transforms: Matrix-based Transforms – Correlation - Basis Functions in the Time-Frequency Plane - Basis Images - Fourier-Related Transforms - Walsh-Hadamard Transforms - Slant Transform - Haar Transform - Wavelet Transforms.			
Unit – 5: Analysis with Color Images Color Image Processing: Color Fundamentals - Color Models - Pseudo color Image Processing - Basics of Full-Color Image Processing - Color Transformations - Color Image Smoothing and Sharpening - Using Color in Image Segmentation - Noise in Color Images -Color Image Compression.			
Course Outcomes			
After completing this course, the students develop the skill set to: CO1: enhance digital images by improving their visual quality. CO2: understand and apply methods such as histogram equalization, contrast stretching, noise reduction, and sharpening CO3: explore various image compression techniques to reduce the storage space and transmission bandwidth required for images. CO4: learn about various linear and non-linear filters to modify images, such as blurring, sharpening, and edge detection filters			

CO5: exposed to real-world applications of digital image processing in fields like medical imaging, remote sensing, computer vision, and multimedia

Text Books

1. Digital Image Processing by Rafael Gonzalez, Richard E. Woods, PHI/Pearson Education, 4th Ed., 2018.
2. Wavelet Analysis with Applications to Image Processing by L.Prasad, S.S.Iyengar, CRC Press, 2015.
3. Fundamentals of Image Processing by A. K. Jain, PHI, 2nd Ed., 2015.
4. Digital Image Processing: Principles and Applications by Gregory A. Baxes, Wiley, 1994.

Reference Books

1. Digital Image Sequence Processing, Compression, and Analysis by Todd R.Reed, CRC Press, 2015.
2. Digital Image Processing and Analysis: Human and Computer Vision Applications with Cviptools by Scott E. Umbaugh, CRC Press, 2nd Ed., 2011.
3. Digital Image Processing: An Algorithmic Introduction Using Java by Wilhelm Burger, Mark J. Burge, Springer Science & Business Media, 2012.
4. Digital Image Processing: PIKS Scientific Inside by William K. Pratt, Wiley, 4th Ed., 2007.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Digital Image Processing by Dr. G. Harit, IIT Kharagpur

Course Code	Course Name	L – T – P	Credits
AM535	Reinforcement Learning	3-0-0	3

Course Objectives:

The aim of the course will be to familiarize the students with the basic concepts as well as with the state-of-the-art research literature in deep reinforcement learning.

Course Contents

Unit – 1: Introduction to Reinforcement Learning

Introduction-Reinforcement Learning-Reinforcement Learning as MDP-Learnable Functions in Reinforcement Learning-Deep Reinforcement Learning Algorithms-Policy-based Algorithms-Value-based Algorithms-Model-based Algorithms-Combined Methods-On-policy and Off-policy Algorithms- Deep Learning for Reinforcement Learning- Reinforcement Learning and Supervised Learning-Lack of an Oracle-Sparsity of Feedback

Unit – 2: Bandit Algorithms

The Reinforcement Learning problem: evaluative feedback, nonassociative learning, Rewards and returns, Markov Decision Processes, Value functions, optimality and approximation. Bandit Problems: Explore-exploit dilemma, Binary Bandits, learning automata, exploration schemes Dynamic programming: value iteration, policy iteration, asynchronous DP, generalized policy iteration

Unit – 3: Monte-Carlo Methods

Monte-Carlo methods: policy evaluation, roll outs, on policy and off policy learning, importance sampling Temporal Difference learning: TD prediction, Optimality of TD (0), SARSA, Q-learning, R-learning, Games and after states. Eligibility traces: n-step TD prediction, TD (lambda), forward and backward views, Q(lambda), SARSA (lambda), replacing traces and accumulating traces

Unit – 4: Gradient Analysis

Function Approximation: Value prediction, gradient descent methods, linear function approximation, Control algorithms, Fitted Iterative Methods Policy Gradient methods: non-associative learning - REINFORCE algorithm, exact gradient methods, estimating gradients, approximate policy gradient algorithms, actor-critic methods

Unit – 5: Different Framework under Reinforcement Learning

Hierarchical RL: MAXQ framework, Options framework, HAM framework, Option discovery algorithms
Case studies: Elevator dispatching, Samuel's checker player, TDgammon, Acrobot, Helicopter piloting, Computational Neuroscience

Course Outcomes

After completing this course, the students develop the skill set to:

- CO1:** structure a reinforcement learning problem
- CO2:** understand and apply basic RL algorithms for simple sequential decision-making problems in uncertain conditions
- CO3:** evaluate the performance of the solution
- CO4:** interpret state-of-the-art RL research and communicate their results
- CO5:** gain understanding of exploration-exploitation trade-off in reinforcement learning and understand different strategies to balance exploration and exploitation, such as epsilon-greedy, upper confidence bounds (UCB), and Thompson sampling.

Text Books

1. Reinforcement Learning - An Introduction by R. S. Sutton and A. G. Barto., MIT Press. 1998.
2. Foundations of Deep Reinforcement Learning Theory and Practice in Python by Laura Graesser, Wah Loon Keng, , Addison-Wesley Professional, 2019.
3. Reinforcement Learning and Optimal Control by Dimitri Bertsekas, Athena Scientific, 2019.

Reference Books

1. Algorithms for Reinforcement learning by Csaba Szepesvari.. Morgan & Claypool Publishers.
2. Reinforcement Learning: State-of-the-Art by Marco Wiering and Martijn van Otterlo, Eds.. Sprinkler.
3. Artificial Intelligence: A Modern Approach by Stuart J. Russell and Peter Norvig.. Pearson.
4. Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville.. MIT Press.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Reinforcement Learning by Dr. B. Ravindran, IIT Madras

Course Code	Course Name	L – T – P	Credits
AM536	Data Mining Techniques	3-0-0	3
Course Objectives: To pre-process and analyze data, to choose relevant models and algorithms for respective applications and to develop research interest towards advances in data mining. To understand the concepts of data mining, issues and applications. To pre-process and analyze data, to select appropriate models and algorithms for respective applications and to develop research interest towards advances in data mining. To learn various data mining techniques like classification, clustering, association rule mining.			
Course Contents			
Unit – 1: Introduction and Data Pre-processing Data Mining – Kinds of data to be mined-Kinds of patterns to be mined-Technologies-Targeted Applications-Major Issues in Data Mining-Data Objects and Attribute Types-Measuring Data similarity and dissimilarity-Data Cleaning-Data Integration-Data Reduction-Data Transformation – Data Discretization.			
Unit – 2: Mining Frequent Patterns and Advanced Pattern Mining Basic Concepts – Frequent Itemset Mining Methods – Pattern Evaluation Methods – Pattern Mining in Multilevel, Multidimensional space – Constraint-Based Frequent Pattern Mining – Mining Compressed or Approximate Patterns – Pattern Exploration and Application.			
Unit – 3: Classification Techniques Basic Concepts–Decision Tree Induction– Bayes Classification Methods – Rule-Based Classification– Model Evaluation and Selection-Techniques to Improve Classification Accuracy – Bayesian Belief Networks – Classification by Backpropagation – Support Vector Machines.			
Unit – 4: Clustering Techniques Cluster Analysis-Partitioning Methods-Hierarchical Methods-Density-Based Methods			
Unit – 5: Outlier Detection and Applications Outliers and Outlier Analysis-Clustering-Based Approach – Classification-Based Approach-Mining Complex Data Types-Data Mining Applications.			
Unit – 6: Data Mining Trends and Research Frontiers Mining Complex Data Types - Other Methodologies - Data Mining Applications - Data Mining and Society – Data Mining Trends			
Course Outcomes			
After completing this course, the students develop the skill set to: CO1: understand different types of data to be mined and categorize the scenario for applying different data mining techniques CO2: evaluate different models used for classification and Clustering and focus towards research and innovation CO3: understand the fundamental concepts of data mining and preprocessing, and further analyze and evaluate the performance of Association Rule Mining algorithms CO4: understand the classification concepts and the working principles of different algorithms CO5: apply the clustering techniques to carry out simple data mining tasks and analyze their performance			

Text Books
1. Data Mining Concept and Techniques by Jiawei Han, Micheline Kamber and Jian Pie, Morgan and Kaufmann Publisher, Third Edition, 2012. 2. Data Mining Techniques by Arun K Pujari, Second Edition, Universities Press India Pvt. Ltd. 2010. 3. Introduction to Data Mining (2nd ed.) by Tan, P.-N., Steinbach, M., Karpatne, A., & Kumar, V., 2018.
Reference Books
1. Data Mining and Predictive Analytics by Daniel T. Larose and Chantal D. Larose, Wiley Series on Methods and Applications in Data Mining, Wiley Publications, 2nd Ed., 2015. 2. Data Mining: Practical Machine Learning Tools and Techniques by Ian H. Witten, Eibe Frank and Mark A. Hall, Morgan and Kaufmann Publisher, 3rd Ed., 2014. 3. Pattern Recognition and Machine Learning by Bishop, C. M. , 2006. 4. The Elements of Statistical Learning: Data Mining, Inference, and Prediction by Hastie, T., Tibshirani, R., & Friedman, J., 2009.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Data Mining by Prof. Pabitra Mitra, IIT Kharagpur

Course Code	Course Name	L – T – P	Credits
AM537	Mathematical Cryptography	3-0-0	3

Course Objectives:

This course aims to understand the importance of cryptanalysis in our increasingly computer-driven world, build fundamentals of Cryptography, Lattice- based cryptanalysis, elliptic curves and pairings, birthday-based algorithms for functions, attacks on stream ciphers and further learn to apply the techniques for secure transactions in real world applications.

Course Contents

Unit- 1: Introduction to Modern Cryptography

Preliminaries, Defining Security in Cryptography Monoalphabetic Ciphers: Using Direct Standard Alphabets, The Caesar Cipher, Modular arithmetic, Direct Standard alphabets, Solution of direct standard alphabets by completing the plain component, solving direct standard alphabets by frequency considerations, Alphabets based on decimations of the normal sequence, Solution of decimated standard alphabets, Monoalphabets based on linear transformation. Polyalphabetic Substitution: Polyalphabetic ciphers, Recognition of polyalphabetic ciphers, Determination of number of alphabets, Solution of individual alphabets if standard, Polyalphabetic ciphers with a mixed plain sequence, Matching alphabets, Reduction of a polyalphabetic cipher to a monoalphabetic ciphers with mixed cipher sequences

Unit – 2: Transposition

Columnar transposition, Solution of transpositions with Completely filled rectangles, incompletely filled rectangles, Solution of incompletely filled rectangles – Probable word method, incompletely filled rectangles general case, Repetitions between messages; identical length messages. Sieve algorithms: Introductory example: Eratosthenes’s sieve, Sieving for smooth composites

Unit – 3: Brute force Cryptanalysis

Introductory example: Dictionary attacks, Brute force and the DES Algorithm, Brute force as a security mechanism, Brute force steps in advanced cryptanalysis, Brute force and parallel computers. The birthday paradox: Sorting or not?: Introductory example: Birthday attacks on modes of operation, Analysis of birthday paradox bounds, Finding collisions, Application to discrete logarithms in generic groups.

Unit – 4: Birthday- based algorithms for functions

Algorithmic aspects, Analysis of random functions, Number-theoretic applications, A direct cryptographic application in the context of block wise security, Collisions in hash functions. Attacks on stream ciphers: LFSR- based key stream generators, Correlation attacks, Noisy LFSR model, Algebraic attacks, Extension to some non- linear shift registers, The cube attack.

Unit – 5: Lattice- based cryptanalysis

Direct attacks using lattice reduction, Coppersmith's small roots attacks. Elliptic curves and pairings: Introduction to elliptic curves, The Weil pairing, the elliptic curve factoring method.

Course Outcomes

After completing this course, the students develop the skill set to:

- CO1:** apply cryptanalysis in system design to protect it from various attacks.
- CO2:** identify and investigate vulnerabilities and security threats and the mechanisms to counter them.
- CO3:** analyze security of cryptographic algorithm against brute force attacks, birthday attacks.
- CO4:** Explore the applications of cryptography in secure communications, digital currencies, and data protection.
- CO5:** Understand and apply the principles of public-key cryptography

Text Books

1. Elementary Cryptanalysis: A Mathematical Approach by Abraham Sinkov, The mathematical Association of America (Inc).
2. Algorithmic Cryptanalysis by Antoine Joux, CRC Press.
3. Algebraic Aspects of Cryptography by Neal Koblitz.

Reference Books

1. Algebraic Cryptanalysis by Bard Gregory, Springer, 2009
2. Cryptanalysis of Number Theoretic Ciphers by Sameul S. Wag staff, Champan & Hall/CRC
3. Cryptanalysis: A Study of Cipher and Their Solution by Helen F. Gaines, 1989.
4. Cryptography and Network Security: Principles and Practice" by William Stallings.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Foundations of Cryptography by Prof. Ashish Choudhury, IIIT Bangalore

Course Code	Course Name	L – T – P	Credits
CSMSCD541	Natural Language Processing (NLP)	3-0-0	3
Course Objectives: To understand algorithms for the processing of linguistic information and computational properties of natural languages, conceive basic knowledge on various morphological, syntactic and semantic NLP tasks, familiarize various NLP software libraries and data sets publicly available, to develop systems for various NLP problems with moderate complexity and to learn steps for creating Machine Learning models.			
Course Contents			
Unit – 1: Introduction Introduction - NLP tasks in syntax, semantics, and pragmatics. Applications such as information extraction, question answering, and machine translation. The problem of ambiguity. The role of machine learning. Brief history of the field - N-gram Language Models - The role of language models. Simple N-gram models. Estimating parameters and smoothing. Evaluating language models.			
Unit – 2: Basic NLP Techniques Part Of Speech Tagging and Sequence Labeling - Lexical syntax. Hidden Markov Models (Forward and Viterbi algorithms and EM training) - Basic Neural Networks. Any basic introduction to perceptron and backpropagation			
Unit – 3: Parsing LSTM Recurrent Neural Networks -Syntactic parsing - Grammar formalisms and treebanks. Efficient parsing for context-free grammars (CFGs). Statistical parsing and probabilistic CFGs (PCFGs). Lexicalized PCFGs. Neural shift-reduce dependency parsing.			
Unit – 4: Semantic Analysis Lexical semantics and word-sense disambiguation. Compositional semantics. Semantic Role Labelling and Semantic Parsing.			
Unit – 5: Machine Translation Information Extraction (IE) - Named entity recognition and relation extraction. IE using sequence labelling. -Machine Translation (MT) Basic issues in MT. Statistical translation, word alignment, phrase-based translation, and synchronous grammars.			
Course Outcomes			
After completing this course, the students develop the skill set to: CO1: Describe the concepts of morphology, syntax, semantics, discourse & pragmatics of natural language. CO2: Demonstrate understanding of the relationship between NLP and statistics & machine learning CO3: Discover various linguistic and statistical features relevant to the basic NLP task, namely, spelling correction, morphological analysis, parts-of-speech tagging and syntactic parsing. CO4: Demonstrate the concept of semantic analysis and word sense disambiguation. CO5: Understand the components of machine translation process and develop the model for NLP applications.			

Text Books
1. Speech and Language Processing by Jurafsky Dan and Martin James H., 3rd Ed., 2018. 2. Natural Language Processing with Python" by Steven Bird, Ewan Klein, and Edward Loper, 2009. 3. Foundations of Statistical Natural Language Processing" by Christopher D. Manning and Hinrich Schütze, 1999. 4. Deep Learning for Natural Language Processing" by Palash Goyal, Sumit Pandey, and Karan Jain, 2018.
Reference Books
1. Practical Natural Language Processing by Sowmya Vajjala, Bodhisattwa Majumder, Anuj Gupta, Harshit Surana, 2020. 2. Natural Language Processing with Python by Steven Bird, Ewan Klein, Edward Loper., 2009. 3. Natural Language Processing with PyTorch by Delip Rao and Brian McMahan, 2009.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Natural Language Processing by Prof. Pushpak Bhattacharyya, IIT Baombay

Course Code	Course Name	L – T – P	Credits
CSMSCD542	Pattern Recognition	3-0-0	3
Course Objectives: This course introduces fundamental concepts, theories, and algorithms for pattern recognition and machine learning. Topics include: Pattern Representation, Nearest Neighbor Based Classifier, Bayes Classifier, Hidden Markov Models, Decision Trees, Support Vector Machines, Clustering, and an application of hand-written digit recognition			
Course Contents			
Unit - 1: Introduction What is Pattern Recognition, Data Sets for Pattern Recognition, Different Paradigms for Pattern Recognition. Representation: Data Structures for Pattern Representation, Representation of Clusters, Proximity Measures, Size of Patterns, Abstractions of the Data Set, Feature Extraction, Feature Selection, Evaluation of Classifier, Evaluation of Clustering.			
Unit – 2: Nearest Neighbor Based Classifier Nearest Neighbor Algorithm, Variants of the NN Algorithm use of the Nearest Neighbor Algorithm for Transaction Databases, Efficient Algorithms, Data Reduction, Prototype Selection. Bayes Classifier: Bayes Theorem, Minimum Error Rate Classifier, Estimation of Probabilities, Comparison with the NNC, Naïve Bayes Classifier, Bayesian Belief Network.			
Unit – 3: Hidden Markov Models Markov Models for Classification, Hidden Markov Models, Classification using HMMs. Decision Trees: Introduction, Decision Tree for Pattern Classification, Construction of Decision Trees, splitting at the Nodes, Overfitting and Pruning, Examples of Decision Tree Induction.			

Unit – 4: Support Vector Machines

Introduction, Learning the Linear Discriminant Functions, Neural Networks, SVM for Classification. Combination of Classifiers: Introduction, Methods for Constructing Ensembles of Classifiers, Methods for Combining Classifiers.

Unit – 5: Clustering

Why is Clustering Important, Hierarchical Algorithms, Partitional Clustering, Clustering Large Data Sets. An Application-Hand Written Digit Recognition: Description of the Digit Data, Pre-processing of Data, Classification Algorithms, Selection of Representative Patterns, Results.

Course Outcomes

After completing this course, the students develop the skill set to:

CO1: Describe the concepts of morphology, syntax, semantics, discourse & pragmatics of natural language.

CO2: Demonstrate understanding of the relationship between NLP and statistics & machine learning

CO3: Discover various linguistic and statistical features relevant to the basic NLP task, namely, spelling correction, morphological analysis, parts-of-speech tagging and syntactic parsing.

CO4: Demonstrate the concept of semantic analysis and word sense disambiguation.

CO5: Understand the components of machine translation process and develop the model for NLP applications.

Text Books

1. Pattern Recognition: An Algorithmic Approach by Murthy, M. Narasimha, Devi, V. Susheela, Springer Pub, 1st Ed., 2011.
2. **Pattern Recognition and Machine Learning** by Christopher M. Bishop, 2006.
3. **Pattern Classification** by Richard O. Duda, Peter E. Hart, and David G. Stork, 2001.
4. **Pattern Recognition** by Sergios Theodoridis and Konstantinos Koutroumbas, 2008.

Reference Books

1. Machine Learning by Tom M. Mitchell, Mc Graw Hill, 1997.
2. Fundamentals of Speech Recognition, Lawrence Rabiner and Biing-Hwang Juang. Prentice Hall Pub.
3. **Pattern Recognition and Neural Networks** by Brian D. Ripley, 1996.
4. **Introduction to Statistical Pattern Recognition** by Keinosuke Fukunaga, 1990.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Pattern Recognition by Prof. P.S. Sastry, IISc Bangalore

Course Code	Course Name	L – T – P	Credits
CSMSCD543	Cloud Computing	3-0-0	3

Course Objectives:

To understand cloud computing evolution as a very important computing model, which enables information, software, and shared resources to be provisioned over the network as services in an on-demand manner. It also provides an insight into what is cloud computing and the various services cloud is capable.

Course Contents
Unit – 1: Computing Paradigms High-Performance Computing, Parallel Computing., Distributed Computing., Cluster Computing., Grid Computing, Cloud Computing., Biocomputing, Mobile Computing., Quantum Computing, Optical Computing. Nano computing. Unit – 2: Cloud Computing Fundamentals Motivation for Cloud Computing, The Need for Cloud Computing, Defining Cloud Computing, Definition of Cloud computing, Cloud Computing Is a Service, Cloud Computing Is a Platform, Principles of Cloud computing, Five Essential Characteristics...Four Cloud Deployment Models Unit – 3: Cloud Computing Architecture and Management Cloud architecture, Layer, Anatomy of the Cloud, Network Connectivity in Cloud Computing, Applications, on the Cloud, Managing the Cloud, Managing the Cloud Infrastructure Managing the Cloud application, Migrating Application to Cloud, Phases of Cloud Migration Approaches for Cloud Migration Unit – 4: Cloud Service Models Infrastructure as a Service, Characteristics of IaaS. Suitability of IaaS, Pros and Cons of IaaS, Summary of IaaS Providers, Platform as a Service, Characteristics of PaaS, Suitability of PaaS, Pros and Cons of PaaS, Summary of PaaS Providers, Software as a Service, Characteristics of SaaS, Suitability of SaaS, Pros and Cons of SaaS, Summary of SaaS Providers. Other Cloud Service Models Unit – 5: Cloud Service Providers EMC, EMC IT, Captiva Cloud Toolkit, Google, Cloud Platform, Cloud Storage, Google Cloud Connect, Google Cloud Print, Google App Engine, Amazon Web Services, Amazon Elastic Compute Cloud, Amazon Simple Storage Service, Amazon Simple Queue service, Microsoft, Windows Azure, Microsoft Assessment and Planning Toolkit, SharePoint, IBM, Cloud Models, IBM Smart Cloud, SAP Labs, SAP HANA Cloud Platform, Virtualization Services Provided by SAP, Salesforce, Sales Cloud, Service Cloud: Knowledge as a Service, Rackspace, VMware, Manjrasoft, Aneka Platform
Course Outcomes
After completing this course, the students develop the skill set to: CO1: work with various cloud service providers, such as Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP) and understand the services and technologies offered by these providers, including compute, storage, networking, databases, and analytics. CO2: deploy and manage applications and services in the cloud such as cloud provisioning, configuration management, monitoring, scaling, and load balancing. CO3: understand security and privacy considerations in cloud computing along with security models, authentication and access control mechanisms, data protection techniques, and regulatory compliance in the cloud. CO4: design and implement secure cloud architectures, cloud storage technologies and data management techniques. CO5: cloud cost management strategies and techniques, resource allocation, cost models, pricing options, and optimizing cloud resource usage, cloud migration and integration.

Text Books
1. Essentials of Cloud Computing by K. Chandrasekhran, CRC press, 2014. 2. Cloud Computing: Concepts, Technology & Architecture by Thomas Erl, Zaigham Mahmood, and Ricardo Puttini, 2013. 3. Cloud Computing: A Hands-On Approach by Arshdeep Bahga and Vijay Madisetti, 2013.
Reference Books
1. Cloud Computing: Principles and Paradigms by Rajkumar Buyya, James Broberg and Andrzej M. Goscinski, Wiley, 2011. 2. Distributed and Cloud Computing by Kai Hwang, Geoffery C. Fox, Jack J. Dongarra, Elsevier, 2012. 3. Cloud Security and Privacy: An Enterprise Perspective on Risks and Compliance by Tim Mather, Subra Kumaraswamy, Shahed Latif, O'Reilly, SPD, 2011. 4. Cloud Native Infrastructure: Patterns for Scalable Infrastructure and Applications in a Dynamic Environment by Justin Garrison and Kris Nova, 2017.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Cloud Computing by Prof. Soumya Kanti Ghosh, IIT Kharagpur

Course Code	Course Name	L – T – P	Credits
CSMSCD544	Computer Vision	3-0-0	3
Course Objectives: To introduce students the fundamentals of image formation; develop an appreciation for various issues in the design of computer vision and object recognition systems; and to provide the student with programming experience from implementing computer vision and object recognition applications..			
Course Contents			
Unit – 1: Introduction Motivation, Image Representation and Image Analysis Tasks, Image Representations, a Few Concepts - Image Digitization, Sampling, Quantization, Digital Image Properties, Metric and Topological Properties of Digital Images, Histograms, Entropy, Image Quality, Noise in Images, Color Images, Color Spaces, Cameras: An Overview.			
Unit – 2: Overview of Mathematics Image, its Mathematical and Physical Background Overview / Linearity / The Dirac Distribution and Convolution / Linear Integral Transforms / Images as Linear Systems/ Introduction to Linear Integral Transforms / 1D Fourier Transform / 2D Fourier Transform / Sampling and the Shannon Constraint / Discrete Cosine Transform / Wavelet Transform / Eigen-Analysis / Singular Value Decomposition / Principle Component Analysis / Other Orthogonal Image Transforms / Images as Stochastic Processes / Images as Radiometric Measurements / Image Capture and Geometric Optics / Lens Aberrations and Radial Distortion / Image Capture from a Radiometric Point of View / Surface Reflectance /			

Unit – 3: Segmentation and Data Structures for Image Analysis

Watershed Segmentation / Region Growing Post-Processing / Matching / Matching Criteria / Control strategies of Matching / Evaluation Issues in Segmentation / Supervised Evaluation / Unsupervised Evaluation/Mean Shift Segmentation / Active Contour Models - Snakes / Traditional Snakes and Balloons / Extensions / Gradient Vector Flow Snakes / Geometric Deformable Models - Level Sets and Geodesic Active Contours / Towards 3D Graph-Based Image Segmentation / Simultaneous Detection of Border Pairs / Sub-optimal Surface Detection / Graph Cut Segmentation / Optimal Single and Multiple Surface Segmentation, Levels of Image Data Representation / Traditional Image Data Structures / Matrices / Chains / Topological Data Structures / Relational Structures / Hierarchical Data Structures / Pyramids / Quadrees / Other Pyramidal Structures

Unit – 4: Shape Representation and Description

Region Identification / Contour-Based Shape Representation and Description / Chain Codes / Simple Geometric Border Representation / Fourier Transforms of Boundaries / Boundary Description using Segment Sequences / B-Spline Representation / Other Contour-Based Shape Description Approaches / Shape Invariants / Region-Based Shape Representation and Description / Simple Scalar Region Descriptors / Moments / Convex Hull / Graph Representation Based on Region Skeleton / Region Decomposition / Region Neighborhood Graphs / Shape Classes

Unit – 5: Cluster Analysis and Object Recognition

Concepts of cluster analysis and multidimensional scaling, similarity measures, hierarchical clustering methods, Ward's hierarchical clustering method's, nonhierarchical clustering methods, K-means methods. Clustering based on statistical models, multidimensional scaling and correspondence analysis, perceptual mapping.

Knowledge Representation / Statistical Pattern Recognition / Classification Principles / Classifier Setting / Classifier Learning / Support Vector Machines / Cluster Analysis / Neural Nets / Feed-Forward Networks / Unsupervised Learning / Hopfield Neural Nets / Syntactic Pattern Recognition / Grammars and Languages / Syntactic Analysis, Syntactic Classifier / Syntactic Classifier Learning, Grammar Inference / Recognition as Graph Matching / Isomorphism of Graphs and Sub-Graphs / Similarity of Graphs / Optimization Techniques in Recognition.

Unit – 6: Image Understanding

Image Understanding Control Strategies / Parallel and Serial Processing Control / Hierarchical Control / Bottom-Up Control / Model-Based Control / Combined Control / Non-Hierarchical Control / RANSAC: Fitting via Random Sample Consensus / Point Distribution Models / Active Appearance Models / Pattern Recognition Methods in Image Understanding / Classification-Based Segmentation / Contextual Image Classification / Boosted Cascade of Classifiers for Rapid Object Detection / Scene Labeling and Constraint Propagation / Discrete Relaxation / Probabilistic Relaxation / Searching Interpretation Trees / Semantic Image Segmentation and Understanding / Semantic Region Growing

Course Outcomes

After completing this course, the students develop the skill set to:

CO1: Identify basic concepts, terminology, theories, models and methods in the field of computer vision

CO2: Describe known principles of human visual system

CO3: Describe basic methods of computer vision related to multi-scale representation, edge detection and detection of other primitives, stereo, motion and object recognition

CO4: Extract and describe key features from images using advanced techniques

CO5: Suggest a design of a computer vision system for a specific problem

Text Books
1. Image Processing, Analysis, and Machine Vision by Milan Sonka, Vaclav Hlavac, Roger Boyle. 3rd Ed, Thomson Brooks/Cole Pub. 2. Computer Vision: Algorithms and Applications" by Richard Szeliski, 2022. 3. Multiple View Geometry in Computer Vision" by Richard Hartley and Andrew Zisserman, 2004 4. Deep Learning for Computer Vision" by Rajalingappaa Shanmugamani, 2018.
Reference Books
1. Computer Vision: A Modern Approach by David A. Forsyth and Jean Ponce, Prentice Hall of India, 2006. 2. Introductory Techniques for 3-D Computer Vision by Emanuele Trucco, Alessandro Verri, Prentice Hall, 1998. 3. Computer and Robot Vision by Robert M. Haralick and Linda G. Shapiro, Addison Wesley 4. Learning OpenCV 4: Computer Vision with Python" by Joseph Howse, Joe Minichino, and Vijay Pablo Biresaw, 2020.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Computer Vision by Prof. Jayanta Mukhopadhyay, IIT Kharagpur

Course Code	Course Name	L – T – P	Credits
CSMSCD545	Computer Forensics	3-0-0	3

Course Objectives:

To understand the principles and concepts of computer forensics and understand the techniques used in computer forensics investigations. As computer forensics is a rapidly evolving field, this course focuses on developing the skills to stay updated with the latest technologies, tools, and trends in the industry. In addition, learn to adapt their knowledge and techniques to new challenges and emerging threats.

Course Contents

Unit – 1: Computer Forensics Fundamentals

Introduction to Computer Forensics, Use of Computer Forensics in Law Enforcement, Computer Forensics Assistance to Human Resources/Employment Proceedings, Computer Forensics Services, Benefits of Professional Forensics Methodology, Steps Taken by Computer Forensics Specialists, Who Can Use Computer Evidence?. Types : Types of Military Computer Forensic Technology, Types of Law Enforcement Computer Forensic Technology, Types of Business Computer Forensics Technology.

Unit – 2: Computer Forensics Evidence and Capture: Data Recovery

Data Recovery Defined, Data Backup and Recovery, The Role of Backup in Data Recovery, The Data-Recovery Solution, Case Histories. Evidence Collection and Data Seizure: Why Collect Evidence?, Collection Options, Obstacles, Types of Evidence, The Rules of Evidence, Volatile Evidence, General Procedure, Collecting and Archiving, Methods of Collection, Artifacts, Collection Steps, Controlling Contamination: The Chain of Custody.

Unit – 3: Duplication and Preservation of Digital Evidence

Preserving the Digital Crime Scene, Computer Evidence Processing Steps, Legal Aspects of Collecting And Preserving Computer Forensic Evidence. Computer Image Verification and Authentication: Special Needs of Evidential Authentication, Practical Considerations, Practical Implementation.

Unit – 4: Computer Forensics Analysis: Discovery of Electronic Evidence

Electronic Document Discovery: A Powerful New Litigation Tool, Identification of Data: Timekeeping, Time Matters, Forensic Identification and Analysis of Technical Surveillance Devices. Reconstructing Past Events: How to Become a Digital Detective, Useable File Formats, Unusable File Formats, Converting Files. Networks: Network Forensics Scenario, A Technical Approach, Destruction of Email, Damaging Computer Evidence, International Principles Against Damaging of Computer Evidence, Tools Needed for Intrusion Response to the Destruction of Data, Incident Reporting and Contact Forms

Unit – 5: Current Computer Forensics Tools

Evaluating Computer Forensics Tool Needs, Computer Forensics Software Tools, Computer Forensics Hardware Tools, Validating and Testing Forensics Software.

Course Outcomes

After completing this course, the students develop the skill set to:

CO1: identify, collect, preserve, and analyze digital evidence effectively.

CO2: learn about incident response procedures and techniques, including identifying and mitigating security incidents.

CO3: do malware analysis and analyze reverse-engineer malicious software.

CO4: apply various forensic investigation techniques used in computer forensics, such as disk imaging, file recovery, data carving, network analysis, and memory analysis.

CO5: stay updated with the latest technologies, tools, and trends in the industry.

Text Books

1. Computer Forensics: Computer Crime Scene Investigation by JOHN R. VACCA, Firewall Media.
2. Guide to Computer Forensics and Investigations by Nelson, Phillips Enfinger, Steuart Cengage Learning
3. Computer Forensics by David Cowen, Mc Graw Hill. Brian Carrier
4. Forensic Discovery by Dan Farmer & Wietse Venema, Addison Wesley, 2005.

Reference Books

1. Computer Forensics and Cyber Crime by Marjie T Britz, Pearson Education.
2. File System Forensic Analysis by Addison Wesley, 2005
3. Digital Evidence and Computer Crime by Eoghan Casey, Academic Press, 3rd Ed., 2011
4. Chris Pogue, Cory Altheide, Todd Haverkos, Unix and Linux Forensic Analysis DVD ToolKit, Syngress Inc., 2008
5. Eoghan Casey, Handbook of Digital Forensics and Investigation, Academic Press, 2009

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Information Security and Forensics by Special Series, IIT Madras

Course Code	Course Name	L – T – P	Credits
CSMSCD546	IoT Analytics	3-0-0	3
Course Objectives: To understand IoT analytics, challenges, and connectivity protocols, IoT cloud and integration of Big Data techniques and services. It focuses on inculcating knowledge on creating cloud analytics environment, visualizing IoT Data and getting familiar with IoT analytics applications.			
Course Contents			
Unit – 1: Introduction to Internet of Things and Analytics Introduction to Internet of Things (IoT): Concepts and Definition of IoT – IoT Devices - IoT Networking Connectivity Protocols – IoT Data Messaging Protocols – MQTT, CoAP. IoT Analytics: Data vs big data- Challenges of IoT Analytics Applications - IoT Analytics Lifecycle and Techniques.			
Unit – 2: IoT Cloud and Big Data Integration IoT Cloud and Big Data Integration: Cloud based IoT platform – Data Analytics for IoT – Data Collection – WAZIUP software Platform – IaaS Software Platform - Elastic analytics concepts – designing for scale – Cloud security and analytics – AWS overview - AWS key services for IoT analytics.			
Unit – 3: Strategies and Techniques in Data Collection Strategies and Techniques in Data collection: Designing Data Processing for Analytics – Applying Big Data to Storage – Apache Spark for IoT Data Processing - Solving Industry Specific Problems.			
Unit – 4: Geospatial Analytics to IoT Data Geospatial Analytics to IoT Data: Basics – Vector and Raster Based Methods – Processing Geospatial Data. Data Science for IoT Analytics – Machine Learning Basic – Forecasting IoT data using ARIMA – Deep learning with IoT data.			
Unit – 5: Applications & Case Studies Applications & Case Studies: Data Analysis in Smart Building – Internet of Things Analytics for Smart Cities – IoT Analytics: From Data Collection to Deployment and Operationalization.			
Course Outcomes			
After completing this course, the students develop the skill set to: CO1: Understand the concepts and techniques of IoT Data Analytics Lifecycle and Machine Learning Application in IoT CO2: Develop cognitive IoT solutions, leveraging artificial intelligence and data science. CO3: Examine concepts of cloud based IoT, big data and IoT in various domains CO4: Propose new strategies for organizations to optimize cost benefits using IoT data. CO5: Explore end-to-end data science industry use cases using the data analytics lifecycle.			
Text Books			
1. Analytics for the Internet of things by Andrew Minter, Packt Publishing, 2017. 2. Building Blocks for IoT Analytics by John Soldatos, River Publishers, 2016. 3. Data Analytics for the Internet of Things (IoT): Frameworks, Tools and Applications by Hui-Huang Hsu, 2017.			

4. Designing the Internet of Things by Adrian McEwen, Hakim Cassimally, 2013.
Reference Books
1. Internet of Things: Principles and Paradigms by Rajkumar Buyya, Amir Vahid Dastjerdi, Elsevier, 2016.
2. Essentials of Cloud computing by R. Chandrasekaran, 2 nd Edition, Chapman and Hall/CRC, 2015.
3. Hands on Artificial intelligence for IoT by Amita Kapoor, 1 st Edition, Packt Publishing, 2019.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Introduction to Internet of Things by Prof. Sudip Misra, IIT Kharagpur

Course Code	Course Name	L – T – P	Credits
CSMSCD547	Distributed Databases	3-0-0	3
Course Objectives: To introduce various Distributed Database Applications in real world scenario, learn more about various Distributed Database Techniques and apply efficient Advanced Techniques to solve engineering problems			
Course Contents			
Unit – 1: Introduction to Distributed Databases Features of Distributed versus Centralized Databases, Principles of Distributed Databases, Levels of Distribution Transparency, Reference Architecture for Distributed Databases, Types of Data Fragmentation, Integrity Constraints in Distributed Databases, Distributed Database Design			
Unit – 2: Techniques in Distributed Query Processing and Optimization Translation of Global Queries to Fragment Queries, Equivalence transformations for Queries, Transforming Global Queries into Fragment Queries, Distributed Grouping and Aggregate Function Evaluation, Parametric Queries. Optimization of Access Strategies, A Framework for Query Optimization, Join Queries, General Queries			
Unit – 3: Distributed Transaction Management The Management of Distributed Transactions, A Framework for Transaction Management, Supporting Atomicity of Distributed Transactions, Concurrency Control for Distributed Transactions, Architectural Aspects of Distributed Transactions Concurrency Control, Foundation of Distributed Concurrency Control, Distributed Deadlocks, and Concurrency Control based on Timestamps, Optimistic Methods for Distributed Concurrency Control.			
Unit - 4: Reliability Management Reliability, Basic Concepts, Nonblocking Commitment Protocols, Reliability and concurrency Control, Determining a Consistent View of the Network, Detection and Resolution of Inconsistency, Checkpoints and Cold Restart, Distributed Database Administration, Catalog Management in Distributed Databases, Authorization and Protection			

Unit – 5: Distributed Object Systems and Database Management

Architectural Issues, Alternative Client/Server Architectures, Cache Consistency, Object Management, Object Identifier Management, Pointer Swizzling, Object Migration, Distributed Object Storage, Object Query Processing, Object Query Processor Architectures, Query Processing Issues, Query Execution, Transaction Management, Transaction Management in Object DBMSs, Transactions as Objects Database Integration, Scheme Translation, Scheme Integration, Query Processing Query Processing Layers in Distributed Multi-DBMSs, Query Optimization Issues Transaction Management Transaction and Computation Model, Multidatabase Concurrency Control, Multidatabase Recovery, Object Orientation and Interoperability, Object Management Architecture CORBA and Database interoperability, Distributed Component Object Model, COM/OLE and Database Interoperability, PUSH-Based Technologies

Course Outcomes

After completing this course, the students develop the skill set to:

- CO1:** Understand the principles and architecture of distributed databases.
- CO2:** Explain the advantages and challenges of distributed database systems compared to centralized systems.
- CO3:** Be able to understand and identify the analytical characteristics of Distributed Databases algorithms.
- CO4:** Explain different consistency models used in distributed databases, such as eventual consistency, strong consistency, and causal consistency.
- CO5:** Apply distributed algorithms to solve problems related to consensus, fault tolerance, and coordination in distributed systems.

Text Books

1. Distributed Databases Principles & Systems, Stefano Ceri, Giuseppe Pelagatti, TMH.
2. Principles of Distributed Database Systems, M. Tamer Ozsu, Patrick Valduriez, Pearson Education, 2nd Edition.
3. Distributed Database Systems: Theory and Practice by Y. Richard Yang, 2015.
4. Distributed Systems: An Algorithmic Approach by Sandeep K. S. Gupta, 2011.

Reference Books

1. Distributed Database Systems, Chanda Ray, Pearson.
2. Distributed Database Management Systems, S. K. Rahimi and Frank. S. Haug, Wiley.
3. Distributed Systems: Principles and Paradigms by Andrew S. Tanenbaum and Maarten Van Steen, 2007.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Distributed Systems by Dr. Rajiv Mishra, IIT Kanpur

Course Code	Course Name	L – T – P	Credits
CSMSCD548	Data Security	3-0-0	3
Course Objectives: The course aims to introduce the fundamental concepts of data security, including cryptography, network security, and information assurance. It also explores the emerging trends and technologies in data security, such as blockchain, quantum cryptography, and AI-based security solutions.			
Course Contents			
Pre-requisite: Basic understanding of mathematics concept like Prime numbers, Modulus, Operations over polynomials, and knowledge of any one of the programming language(C/C++/Java/Python)			
Unit - 1: Introduction to Data Security Overview of data security, core goals of security; the CIA, humans aspects in security, Password Management Systems, Security Services, Security Mechanisms			
Unit – 2: Threats and Attack Modes Common threats and attack modes on information systems. Differentiating between threats, attacks, spoofing, malware, and denial of service attacks. Method of attacks in information systems, Security Use Cases.			
Unit – 3: Cryptographic Models for Data Security Classical Encryption Techniques and their Cryptanalysis: Symmetric cipher model, Substitution techniques, Transposition techniques, Steganography, One-Time Pad (Vernam’s Cipher), Limitations of Perfect Secrecy, Shannon’s Theorem, Private-Key Encryption Schemes and Block Ciphers AES, Public-Key (Asymmetric) Cryptography: Public-Key Problems and Mathematical Background, Diffie-Hellman Key Agreement, Hash Functions: Definition and Properties, Constructions of Collision-Resistant Hash Functions, Random Oracle Model. Digital Signature schemes for Authentication			
Unit – 4: Blockchain for Data Integrity Fundamental design and architectural primitives of Blockchain, the system and the security aspects, Basic Distributed System concepts – distributed consensus and atomic broadcast, concepts to Bitcoin and contemporary proof-of-work based consensus mechanisms, crypto-currency as application of blockchain technology			
Unit – 5: Data Access Control Mechanisms Introduction on un-authorize data disclosure, Different access control mechanism: Mandatory access control (MAC), discretionary access control (DAC), role-based access control (RBAC), and rule-based access control (RB-RBAC).			
Course Outcomes			
After completing this course, the students develop the skill set to: CO1: To identify, analyze, and manage security threats and vulnerabilities in various systems and networks CO2: To implement and manage security measures, including encryption, firewalls, intrusion detection systems, and access control mechanisms. CO3: To be aware about the legal, ethical, and privacy issues related to data security, including data protection laws and regulatory requirements CO4: To provide hands-on experience with security tools and technologies through labs, projects, case			

studies
CO5: To communicate security concepts and issues effectively and work collaboratively in teams to address security challenges
Text Books
1. Cryptography & Network Security” by William Stallings 4th Edition, 2006, Pearson Education Asia. 2. Bitcoin and Cryptocurrency Technologies by Arvind Narayanan, Joseph Bonneau, Edward Felten, Andrew Miller, Steven Goldfeder, Princeton University Press 3. Data and Computer Security: Principles and Practices by David Salomon, 2007. 4. Operating System Security by Trent Jaeger,
Reference Books
1. Computer Security: Principles and Practice by William Stallings and Lawrie Brown, 2017. 2. Security Engineering: A Guide to Building Dependable Distributed Systems by Ross Anderson, 2020 3. Introduction to Computer Security by Michael Goodrich and Roberto Tamassia, 2011. 4. Applied Cryptography: Protocols, Algorithms, and Source Code in C by Bruce Schneier, 2015.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Information Security by Prof. V. Kamakoti, IIT Madras

Course Code	Course Name	L – T – P	Credits
CSMSCD549	Advanced Database Management Systems	3-0-0	3

Course Objectives:

This course aims to introduce the database design and systems, learn how data is stored, organized and managed efficiently in a database and further provides the knowledge of transaction processing and concurrency control.

Course Contents

Unit – 1: Databases: Architecture and Management

Database System Architecture: Centralized and Client-Server Architectures, Server system Architectures, Database Architecture, Transaction Management, Data Models and Its Evolution, Degrees of Data Abstraction, Parallel Systems, Distributed Systems, Elastic Search, Network Types; Data Management: Information Systems and Data Databases – SQL Databases – Big Data – No SQL Databases – Organizing of Data Management.

Unit – 2: Data Models

Data Modeling: Data Model-Key-Value Data Model- Columnar Data Model, Graph Based Data Model Graph Data Model, From Data Analysis to Database–The Entity-Relationship Model - Implementation in the Relational Model-Implementation in the Graph Model – Enterprise-wide Data Architecture – Formula for Database Design

Unit – 3: Interactions with Databases

Database Languages: Interacting with Databases-Relational Algebra-Relationally Complete Languages-Graph based Languages-Embedded Languages-Handling NULL Values-Integrity Constraints – Data Protection Issues, Database Design and ER Model, Relational Schemas, RDBMS, Atomic Domain and

Normalization, Relational Algebra, Selection and Projection, Set Operations, Renaming, Joins, Semantics, Grouping And Ungrouping, Relational Comparison, With SQL, Null Values, Nested Sub Queries, Joined Relations.

Unit – 4: Properties of a Database

Ensuring Data Consistency: Multi-user Operation – Transaction Concept – Consistency in Massive Distributed Data – Comparing ACID and BASE, Serializability and Concurrency Control, Lock Based Concurrency Control, Time Stamping Methods, Optimistic Methods, Database Recovery Management, CAP Theorem

Unit – 5: NoSQL Databases

System Architecture: Processing of Homogeneous and Heterogeneous Data – Storage and Access Structure – Translation and Optimization of Relational Queries – Parallel Processing with Map Reduce – Layered Architecture – Use of Different Storage Structures -NoSQL Databases: Need of NoSQL, Value of Relational Databases, impedance mismatch, Application and Integration Databases, Attack of the clusters, Emergence of NoSQL, Development of Non-relational Technologies – Key-value stores – Column-Family Stores – Document Stores – XML Databases – Graph Databases. NoSQL. NoSQL Data Architecture Patterns: NoSQL Data model: Aggregate Models- Document

Unit – 6: Data Storage and Distributed Models

Distributed Models- Single Server, Sharding, Master-Slave Replication, Peer to Peer Replication. Key-Value Databases: Comparison of Relational and Key Value Store, Features. Document Databases: Comparison of Relational and Document Database, Advantages and Disadvantages, Features. Column Family Stores- Comparison of Relational and Column Family, Advantages and Disadvantages

Course Outcomes

After completing this course, the students develop the skill set to:

- CO1:** define database models and database management and explain the applications of database models.
- CO2:** experiment with various database languages.
- CO3:** distinguish the ACID/BASE properties and data consistency
- CO4:** be able to write SQL queries to manipulate data in a RDBMS
- CO5:** appraise and adopt the NoSQL databases for the recent technologies

Text Books

1. Database System Concepts - by Abraham Silberschatz, Henry F.korth,S. Sudarshan, McGraw Hill, 6th Ed., 2013 (Unit : I-IV).
2. Database Management Systems - by R. Ramakrishnan, J. Gehrke, McGraw Hill Education, 3rd Ed., 2014.
3. Fundamental of Database Systems - by Ramez Elmasri, Shamkant B Navathe, 7th Ed., 2016.
4. Database Systems: The Complete Book - by Hector Garcia-Molina, Jeffrey Ullman, Jennifer Widom, Pearson, 2nd Ed., 2008.

Reference Books

1. An Introduction to Database Systems - by C.J. Date, A. Kannan, S. Swamynathan, Pearson Ed. Reprint, 8th Edition, 2016.
2. Database Systems - by Rob Coronel, Course Technology Inc., 7th Ed., 2006.
3. SQL & NoSQL Databases - by Andreas Meier and Michael Kaufmann, Springer, Morgan Kaufmann,

2019.

4. Modern Database Management - by J. Hoffer, R. Venkataraman, H. Topi, Pearson, 12th Ed., 2016.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Introduction to Database Systems by Prof. P.Sreenivasa Kumar, IIT Madras

Course Code	Course Name	L – T – P	Credits
CSMSCD550	Computer Organization and Architecture	3-0-0	3

Course Objectives:

The purpose of the course is to introduce principles of computer organization and the basic architectural concepts. It begins with basic organization, design, and programming of a simple digital computer and introduces simple register transfer language to specify various computer operations. Topics include computer arithmetic, instruction set design, microprogrammed control unit, pipelining and vector processing, memory organization and I/O systems, and multiprocessors.

Course Contents

Unit - 1: Digital Computers

Introduction, Block diagram of Digital Computer, Definition of Computer Organization, Computer Design and Computer Architecture. Register Transfer Language and Micro operations: Register Transfer language, Register Transfer, Bus and memory transfers, Arithmetic Micro operations, logic micro-operations, shift micro-operations, Arithmetic logic shift unit. Basic Computer Organization and Design: Instruction codes, Computer Registers Computer instructions, Timing and Control, Instruction cycle, Memory Reference Instructions, Input – Output and Interrupt.

Unit – 2: Microprogrammed Control

Control memory, Address sequencing, micro program example, design of control unit. Central Processing Unit: General Register Organization, Instruction Formats, Addressing modes, Data Transfer and Manipulation, Program Control.

Unit – 3: Data Representation

Data types, Complements, Fixed Point Representation, Floating Point Representation. Computer Arithmetic: Addition and subtraction, multiplication Algorithms, Division Algorithms, Floating – point Arithmetic operations. Decimal Arithmetic unit, Decimal Arithmetic operations.

Unit – 4: Data Representation

Data types, Complements, Fixed Point Representation, Floating Point Representation. Computer Arithmetic: Addition and subtraction, multiplication Algorithms, Division Algorithms, Floating – point Arithmetic operations. Decimal Arithmetic unit, Decimal Arithmetic operations.

Unit – 5: Input-Output Organization

Input-Output Interface, Asynchronous data transfer, Modes of Transfer, Priority Interrupt Direct memory Access. Memory Organization: Memory Hierarchy, Main Memory, Auxiliary memory, Associate Memory, Cache Memory.

Unit – 6: Reduced Instruction Set Computer

CISC Characteristics, RISC Characteristics. Pipeline and Vector Processing: Parallel Processing, Pipelining, Arithmetic Pipeline, Instruction Pipeline, RISC Pipeline, Vector Processing, Array Processor.

Multi Processors: Characteristics of Multiprocessors, Interconnection Structures, Interprocessor arbitration, Interprocessor communication and synchronization, Cache Coherence.
Course Outcomes
After completing this course, the students develop the skill set to: CO1: Understand the basics of instructions sets and their impact on processor design. CO2: Demonstrate an understanding of the design of the functional units of a digital computer system. CO3: Evaluate cost performance and design trade-offs in designing and constructing a computer processor including memory. CO4: Design a pipeline for consistent execution of instructions with minimum hazards CO5: Recognize and manipulate representations of numbers stored in digital computers
Text Books
1. Computer System Architecture by M. Moris Mano, Pearson Education/ Prentice Hall of India, 3rd Ed., 2010. 2. Computer Organization and Design: The Hardware/Software Interface by David A. Patterson, John L. Hennessy, Morgan Kauffman, 5th Ed., 2013. 3. Computer Systems: A Programmer's Perspective by Randal Bryant, David O'Hallaron, Pearson, 3rd Ed., 2015. 4. Computer Architecture: A Quantitative Approach by John L. Hennessy, David A. Patterson, Morgan Kauffman, 6th Ed., 2017.
Reference Books
1. Computer Organization and Architecture: Designing for Performance by William Stallings, Pearson Education, 9th Ed., 2013. 2. Structured Computer Organization by A. S. Tanenbaum, Pearson Education India, 6th Ed., 2016. 3. Computer Organization by Car Hamacher, Zvonks Vranesic, Safea Zaky, McGraw Hill, 5th Ed., 2011.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Computer Architecture and Organization by Prof. Indranil Sengupta, Prof. Kamalika Datta, IIT Kharagpur 2. NPTEL Lecure on Computer Organization and Architecture (Web) by Prof. Bhaskaran Raman, IIT Kanpur

Course Code	Course Name	L – T – P	Credits
CSMSCD551	Generative AI	3-0-0	3
Course Objectives: The objective of this course is to provide students with a comprehensive understanding of Generative AI, its theoretical foundations, and practical applications. Students will learn to develop, evaluate, and deploy generative models in various domains, leveraging state-of-the-art techniques and tools.			
Course Contents			
Unit – 1: Introduction to Generative AI Overview of generative AI, Types of generative models, Applications of generative AI, Probabilistic Models, Bayesian networks, Markov Chains and Monte Carlo Methods, Ethical Considerations in Generative AI Unit – 2: Autoencoders Autocoders fundamentals, Variational Autoencoders (VAEs) and its mathematical Foundations, Encoder-Decoder Architecture, Training and Optimization, Applications of VAEs Unit – 3: Generative Adversarial Networks (GANs) Introduction to GANs, Architecture, Training Techniques and Challenges, Variants of GANs (DCGAN, CycleGAN, StyleGAN), Applications of GANs Unit – 4: Reinforcement Learning for Generative Models Basics of reinforcement learning, Policy gradients, Reinforcement learning for generative models, and Generative models for unsupervised learning.			
Unit – 5: Applications of AI Case Studies of Generative AI-Image generation, Text generation, Music generation, Video Generation, and Audio Synthesis			
Course Outcomes			
After completing this course, the students develop the skill set to: CO1: Understand the fundamental concepts and mathematical foundations of Generative AI. CO2: Develop and implement various generative models such as GANs, VAEs, and autoregressive models. CO3: Apply generative models to real-world problems including image, text, and audio generation. CO4: Understand ethical considerations and challenges associated with Generative AI. CO5: Utilize advanced tools and frameworks for developing generative AI solutions.			
Text Books			
1. Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play by David Foster, 2020. 2. Hands-On Generative Adversarial Networks with Keras by Rafael Valle, 2019. 3. Probabilistic Graphical Models: Principles and Technique by Daphne Koller and Nir Friedman, 2009. 4. Generative Adversarial Networks: Build and Train Your First Models by Marek Kannawadi, 2020. 5. GANs in Action: Deep learning with Generative Adversarial Networks by Jakub Langr and Vladimir B., 2018.			

Reference Books
1. Deep Learning with Python by Francois Chollet, 2017. 2. Natural Language Processing with PyTorch by Delip Rao and Brian McMahan, 2019. 3. Reinforcement Learning: An Introduction by Richard S. Sutton and Andrew G. Barto, 2018. 4. Deep Reinforcement Learning Hands-On by Maxim Lapan, 2018. 5. Ethics of Artificial Intelligence and Robotics by Vincent C. Müller, 2020. 6. Artificial Intelligence: Foundations of Computational Agents by David L. Poole and Alan K. Mackworth, 2017.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1. NPTEL Lecture on Artificial Intelligence by Prof. P. Dasgupta, IIT Kharagpur 2. NPTEL Lecture on An Introduction to Artificial Intelligence by Prof. Mausam, IIT Delhi

Course Code	Course Name	L – T – P	Credits
CSMSCD552	Advanced NLP with LLMs	3-0-0	3

Course Objectives:

The objective of this course is to provide students with a comprehensive understanding of Large Language Models (LLMs), their underlying principles, applications, and implications. Students will explore the architecture, training methodologies, and performance evaluation of LLMs, while gaining hands-on experience in implementing and fine-tuning these models for various natural language processing (NLP) tasks.

Course Contents

Unit – 1: Introduction to LLMs

Overview of Natural Language Processing (NLP), Evolution of Language Models: From n-grams to Transformers, Introduction to LLMs: GPT, BERT, T5, and others, Applications of LLMs in various domains

Unit – 2: Language Model Architectures

Basics of Autoregressive Models, Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTM), Transformer Models and Attention Mechanisms, Applications in Text Generation and Sequence Modeling, RNNs, LSTMs, GRUs, and Transformers, Attention Mechanism and Self-Attention, Pre-training and Fine-tuning Paradigms

Unit – 3: Model Evaluation and Interpretation

Evaluation Metrics for Language Models: Perplexity, BLEU, ROUGE, Interpretability and Explainability of LLMs, Debugging and Error Analysis, Performance Evaluation of GPT, BERT, and T5

Unit – 4: Autoregressive Models

Transfer Learning and Domain Adaptation, Few-Shot and Zero-Shot Learning, Multimodal LLMs: Combining Text with Other Modalities, LLMs in Multilingual and Low-Resource Settings

Unit – 5: Applications of AI

Implementing and Fine-tuning LLMs using frameworks like Hugging Face Transformers, Real-world Case Studies and Applications, Developing and Evaluating LLM-based Solutions

Course Outcomes	
After completing this course, the students develop the skill set to: CO1: Analyze and evaluate the performance of different LLMs for various NLP tasks. CO2: Critically assess the ethical and societal implications of deploying LLMs. CO3: Understand the theoretical foundations and architecture of Large Language Models. CO4: Implement and fine-tune LLMs for specific applications using state-of-the-art frameworks. CO5: Conduct independent research in LLMs and contribute to advancements in the field.	
Text Books	
1. Deep Learning for Natural Language Processing by Palash Goyal, Sumit Pandey, Karan Jain, 2018. 2. Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, 2016. 3. Natural Language Processing with Python by Steven Bird, Ewan Klein, and Edward Loper, 2009. 4. Speech and Language Processing by Daniel Jurafsky and James H. Martin, 2021. 5. Transformers for Natural Language Processing by Denis Rothman, 2021.	
Reference Books	
1. Hands-On Generative Adversarial Networks with Keras by Rafael Valle, 2019. 2. Deep Learning with Python by Francois Chollet, 2018. 3. Natural Language Processing with PyTorch by Delip Rao and Brian McMahan, 2019. 4. Artificial Intelligence: A Guide for Thinking Humans by Melanie Mitchell, 2019. 5. Artificial Intelligence: Foundations of Computational Agents by David L. Poole and Alan K. Mackworth, 2017.	
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]	
1. NPTEL Lecture on Applied Natural Language Processing by Prof Ramaseshan, CMI	

Course Code	Course Name	L – T – P	Credits
TMMSCD550	Business Economics and Financial Analysis	3-0-0	3
Course Objectives: To learn the basic Business types, impact of the Economy on Business and Firms specifically. To analyze the Business from the Financial Perspective.			
Course Contents			
Unit – 1: Introduction to Business and Economics Business: Structure of Business Firm, Theory of Firm, Types of Business Entities, Limited Liability Companies, Sources of Capital for a Company, Non-Conventional Sources of Finance. Economics: Significance of Economics, Micro and Macro Economic Concepts, Concepts and Importance of National Income, Inflation, Money Supply in inflation, Business Cycle, Features and Phases of Business Cycle. Nature and Scope of Business Economics, Role of Business Economist, Multidisciplinary nature of Business Economics.			
Unit – 2: Demand and Supply Analysis Elasticity of Demand: Elasticity, Types of Elasticity, Law of Demand, Measurement and Significance of Elasticity of Demand, Factors affecting Elasticity of Demand, Elasticity of Demand in decision making, Demand Forecasting: Characteristics of Good Demand Forecasting, Steps in Demand Forecasting,			

Methods of Demand Forecasting. Supply Analysis: Determinants of Supply, Supply Function & Law of Supply.

Unit – 3: Production, Cost, Market Structures & Pricing

Production Analysis: Factors of Production, Production Function, Production Function with one variable input, two variable inputs, Returns to Scale, Different Types of Production Functions. Cost analysis: Types of Costs, Short run and long run Cost Functions. Market Structures: Nature of Competition, Features of Perfect competition, Monopoly, Oligopoly, Monopolistic Competition. Pricing: Types of Pricing, Product Life Cycle based Pricing, Break Even Analysis, Cost Volume Profit Analysis.

Unit – 4: Financial Accounting

Accounting concepts and Conventions, Accounting Equation, Double-Entry system of Accounting, Rules for maintaining Books of Accounts, Journal, Posting to Ledger, Preparation of Trial Balance, Elements of Financial Statements, Preparation of Final Accounts.

Unit – 5: Financial Analysis through Ratios

Financial Analysis through Ratios: Concept of Ratio Analysis, Liquidity Ratios, Turnover Ratios, Profitability Ratios, Proprietary Ratios, Solvency, Leverage Ratios (simple problems). Introduction to Fund Flow and Cash Flow Analysis (simple problems).

Course Outcomes

After completing this course, the students develop the skill set to:

CO1: Understand the various forms of business and the impact of economic variables on the Business.

CO2: Explain fundamental economic principles and theories, demand, supply, production, cost, market structure, pricing aspects

CO3: Study the firm's financial position by analysing the Financial Statements of a Company.

CO4: Apply various financial analysis techniques, such as ratio analysis, trend analysis, and financial forecasting, to evaluate the financial health of businesses and make informed financial decisions.

CO5: Recommend business strategies and financial plans based on comprehensive economic and financial analysis

Text Books

1. Business Economics - Theory and Applications by D.D. Chaturvedi, S.L. Gupta, 2013.
2. Financial Accounting by Dhanesh K Khatri, 2011.
3. Managerial Economics by Geethika Ghosh, Piyali Gosh, Purba Roy Choudhury, 2012.
4. Principles of Managerial Economics" by James R. McGuigan, R. Charles Moyer, and Fredrick H. deB. Harris, 2020.

Reference Books

1. Financial Accounting for Management by Paresh Shah, 2015.
2. Financial Accounting by S.N. Maheshwari, Sunil K Maheshwari, Sharad K Maheshwari, 2013.
3. Managerial Economics: Theory, Applications, and Cases" by William F. Samuelson and Stephen G. Marks, 2018.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Managerial Economics by Prof. Barnali Nag, IIT Kharagpur

Course Code	Course Name	L – T – P	Credits
SRMSCD560	Symbolic AI	3-0-0	3
Course Objectives: The primary objective of this course is to provide students with a comprehensive understanding of Symbolic Artificial Intelligence (SAI). Students will explore the theoretical foundations, methodologies, and applications of symbolic AI, enabling them to design and implement AI systems that utilize symbolic reasoning, knowledge representation, and logic.			
Course Contents			
Unit – 1: Introduction to LLMs Definition and history of Symbolic AI, Comparison with other AI paradigms (e.g., sub-symbolic AI, hybrid AI), Applications of Symbolic AI Unit 2: Knowledge Representation Logical representation: propositional logic, first-order logic, Semantic networks, Frames and scripts, Ontologies, Rule-based systems Unit – 3: Language Model Architectures Inference mechanisms: forward chaining, backward chaining, Resolution and unification, Constraint satisfaction problems (CSPs), Automated theorem proving, Problem-solving as search, Classical search algorithms: BFS, DFS, A*, Heuristic search, Planning algorithms: STRIPS, Graph Plan, SAT Plan Unit – 4: Natural Language Processing with Symbolic AI Syntax and parsing, Semantic analysis, Pragmatics and discourse, Symbolic approaches to machine translation and question answering Unit – 5: Integration with Other AI Techniques Combining symbolic and sub-symbolic methods (e.g., neural-symbolic integration), Hybrid AI systems, Case studies of integrated AI applications			
Course Outcomes			
After completing this course, the students develop the skill set to: CO1: Understand the principles and theories underlying Symbolic AI. CO2: Implement symbolic AI techniques in problem-solving and knowledge representation. CO3: Develop and apply symbolic reasoning methods to real-world scenarios. CO4: Critically analyze and evaluate symbolic AI systems and their performance. CO5: Integrate symbolic AI with other AI paradigms and technologies.			
Text Books			
1. Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Norvig, 2010. 2. Knowledge Representation and Reasoning by Ronald Brachman and Hector Levesque, 2004. 3. Artificial Intelligence: Structures and Strategies for Complex Problem Solving" by George F. Luger, 2008. 4. Logical Foundations of Artificial Intelligence by Michael Genesereth and Nils Nilsson, 1987.			

Reference Books	
1. Building Expert Systems: Principles, Procedures, and Applications by Frederick Hayes-Roth, Donald A. Waterman, and Douglas B. Lenat, 1983. 2. Natural Language Processing with Python by Steven Bird, Ewan Klein, and Edward Loper, 2009. 3. Hybrid Artificial Intelligence Systems edited by Mourad Elloumi, Antonio Granados, and José Manuel Gómez-Pérez"Artificial Intelligence: A Guide for Thinking Humans by Melanie Mitchell, 2019. 4. Artificial Intelligence: Foundations of Computational Agents by David L. Poole and Alan K. Mackworth, 2017.	
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]	
1. NPTEL Lecture on Artificial Intelligence by Prof. P. Dasgupta, IIT Kharagpur 2. NPTEL Lecture on An Introduction to Artificial Intelligence by Prof. Mausam, IIT Delhi	

Course Code	Course Name	L – T – P	Credits
SRMSCD561	Data-driven Robotics and Learning Control	3-0-0	3

Course Objectives:

This course aims to provide an in-depth understanding of data-driven techniques in robotics and control systems. It focuses on learning control algorithms, data-driven modeling, and the application of machine learning methods to robotic systems. The course integrates theoretical knowledge with practical skills, preparing students for advanced research and industry roles in robotics and control systems.

Course Contents

Unit – 1: Introduction to Robotics and Control Systems

Fundamentals of robotics and control systems, Types of robots and their applications, Basics of control theory, Classical control methods (PID, state-space models), Introduction to data-driven approaches in control

Unit – 2: Data-driven Modeling

Data collection and preprocessing for robotic systems, System identification and model selection, Machine learning for system modeling, Time-series analysis and prediction, Case studies of data-driven modeling in robotics

Unit – 3: Learning Control Algorithms

Introduction to learning control, Reinforcement learning for control systems, Adaptive control methods, Model predictive control (MPC), Neural network-based control algorithms, Implementing learning control algorithms

Unit – 4: Machine Learning in Robotics

Supervised and unsupervised learning in robotics, Feature extraction and selection for robotic data, Dimensionality reduction techniques, Deep learning for perception and control, Transfer learning and domain adaptation, Case studies of machine learning in robotics

Unit – 5: Optimization and Performance Evaluation

Optimization techniques for control systems, Performance metrics for control systems, Simulation and real-time implementation, Robustness and reliability in data-driven control, Case studies of performance evaluation

Unit 6: Advanced Topics and Applications Multi-agent systems and cooperative control, Human-robot interaction and learning, Autonomous navigation and path planning, Application of data-driven control in industry, Ethical and societal implications of robotics, Current trends and future directions in data-driven robotics
Course Outcomes After completing this course, the students develop the skill set to: CO1: Understand and apply data-driven modeling techniques to robotic and control systems. CO2: Design and implement learning control algorithms. CO3: Utilize machine learning methods to optimize and control robotic systems. CO4: Analyze and evaluate the performance of data-driven control systems. CO5: Develop solutions for real-world robotic control problems using data-driven approaches.
Text Books 1. Robotics: Modelling, Planning and Control by Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, Giuseppe Oriolo, 2010. 2. Reinforcement Learning: An Introduction by Richard S. Sutton and Andrew G. Barto, 2018. 3. Machine Learning: A Probabilistic Perspective by Kevin P. Murphy, 2012. 4. Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control by Steven L. Brunton and J. Nathan Kutz, 2019. 5. Adaptive Control by Karl J. Åström and Björn Wittenmark, 2013.
Reference Books 1. Neural Network Design by Martin T. Hagan, Howard B. Demuth, and Mark H. Beale, 1996. 2. Introduction to Autonomous Robots: Mechanisms, Sensors, Actuators, and Algorithms by Nikolaus Correll, Bradley Hayes, and David Lesser 2017. 3. Modern Control Engineering by Katsuhiko Ogata, 2009.
Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.] 1. NPTEL Lecture on Robotics and Control : Theory and Practice by Prof. N. Sukavanam and Prof. M. Felix Orlando

M.Sc. in Tank Technology

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M.Sc. In Tank Technology

CREDITS FOR MSC TANK TECHNOLOGY DEGREE FROM DIAT GIRINAGAR PUNE FOR TANK TECH COURSE CONDUCTED AT ACC&S AHILYANAGAR

Semester I				Semester II			
<u>S.No.</u>	<u>Course Type</u>	<u>Course Code</u>	<u>Credits</u>	<u>S.No.</u>	<u>Course Type</u>	<u>Course Code</u>	<u>Credits</u>
1	PC - 1	<u>TTC</u> 501	4	1	PC - 5	<u>TTC</u> 507	4
2	PC - 2	<u>TTC</u> 502	4	2	PC - 6	<u>TTC</u> 508	3
3	PC - 3	<u>TTC</u> 503	3	3	PE - I	<u>TTC</u> 509	3
4	PC - 4	<u>TTC</u> 504	3	4	PE - II	<u>TTC</u> 510	3
5	LAB	<u>TTC</u> 505	2	5	PE - III	<u>TTC</u> 511	3
6	PGC	<u>TTC</u> -506	4	6	On-Job Training/Field Project (120 Hrs)	<u>TTC</u> 512	4
		Total	20			Total	20

On Job Training(OJT) evaluation to be conducted at the end of first year.
For exit at the end of first year, the student has to clear and extra 3 credit course (PC/PE/NPTEL) as decided by the BoS.

Maximum of 6 Credits to be awarded for Professional Electives (approved by BoS) for Online Courses NPTEL During (II & III Semester)

Semester III				Semester IV			
<u>S.No.</u>	<u>Course Type</u>	<u>Course Code</u>	<u>Credits</u>	<u>S.No.</u>	<u>Course Type</u>	<u>Course Code</u>	<u>Credits</u>
1	PC-7	TTC 513	4	1	Project 2	TTC 519	18
2	PC-8	TTC 514	3			Total	18
3	PE-IV	TTC 515	3				
4	PE-V	TTC 516	3				
5	PE-VI	TTC 517	3				
6	Project 1	TTC 518	6				
		Total	22				

*Underlined course codes as per department/school nomenclature.

For MTech/MSc Programmes for working professionals and MTech/MSc online programmes, the semester credit requirements should be followed and structured to be approved by PGC Chariman and Academics Dean before proceeding for BoS approvals.

MSc Programme Structure:

PC is programme Core course and PE is professional elective

SCHOOL OF DEFENCE TECHNOLOGY and MANAGEMENT

SYLLABUS FOR M Sc IN TANK TECHNOLOGY

SEMESTER - I

Course Type **(PC-1)**. - Advance Electronic Designing & Its Application

Course Code - TTC 501

1. **Unit I : Basic Electronics & Communication Technology.** Antennas Fundamentals, Propagation Models, Microelectronics Characteristics and Behavior, Guided Waves, Radio & Frequency Microwave Power Dividers, Electromagnetic Devices. Receiver Design and Charge, Analogy & Digital Signature processing, Coding, Source, Channel, Communication System Design, Satellite & Radio Relay Technology.
2. **Unit II : Internet of Things & Artificial Intelligence.** Communication & Networking protocols, Integration with cloud computing, Networking Security Technology, Appliances in Military Systems. Supervised, Semi-Supervised, Unsupervised, Computer vision, Neural Networking Implementation, Software Target Techniques, Military appliances& its Latest Research & Development.
3. **Unit III : Radar, Nano Technology & Quantum Technology.** Technology Aspects, Radar Detection Technology, Pulsed Radar Characteristics and Technology, Radar Cross-Section: Radiations Technology, Radar Performance: Improvement Technology, Radar Electronic Warfare, Latest Trends. Material Study, Micro Sensors & Actuators, Nano CMOS Circuits Design, Carbon Nano Tube, Nano Fabrication Technology. Cryptography Technology, Entanglement : Concept and Use, Quantum Optics: Technology Requirement, Quantum Security : Architecture, Design and Methodology.

Reference Books.

1. Introduction to Radar Systems by Merrill I Skolnik
2. Defence Electronics : Design, Develop, and Deploy by VK Jain
3. Military Communications : A Test Bed for Future Networking Applications by George AO Dell

Text Books.

1. Hand book of Defence, Electronics and, Optronics : Fundamentals, Technologies and Systems by Anil K Maini
2. Microelectronics : Circuit Design and Application by Richard C. Jaeger and Travis N. Blalock
3. Electronic Defence Systems by D C Agarwal

Course Objectives.

CO 1: Deepen Understanding of Advanced Electronic Design.

CO 2 : Master Simulation Tools and Techniques.

CO 3 : Design High Performance Power Electronics systems.

Course Outcome. After completing this Course, the students will be able to:-

CO 1 :Advanced Circuit Design Proficiency - Communication Power, electronics and embedded System.

CO 2 :Power Electronics System Design – Students will have the ability to design and simulate efficient power electronics Systems, Such as DC-DC converters, inverters and power supplies.

CO 3 :Custom Component Modelling and Simulation – Students will be capable of modelling and simulating custom components and complex non-ideal behaviors in LTSpice for more accurate and tailored designs.

Course Type **(PC-2).** - Electronic System & Its Integration

Course Code TTC 502

1. **Unit I : Integrated Circuits & Bridging Module.** Integrated Circuits
Reading and Design, Printed Circuit Boards : Integrated, Printing & Design.
Fundamentals of Electronics Engineering, Micro-Electronics : Microcontrollers
Technology, Microprocessors, Digital Electronics, Battery Management System, Tank

Electronics with Basic Interpersonal Communication Skills, General Staff Qualitative requirements / Provisional Staff Qualitative Requirements.

2. **Unit II : Vehicles System Integrated, Unmanned Aerial Vehicles & Drones.**

Sensors & Commercial Off-the-Shelf Components, Sensor Integrated Methods, Hardware & Software Integrated, Architecture Design : Functional & Physical Design, System Testing. Power Management : Payload and Frame Form, Communication - Controller to Slave, Slave to Trained Graduate Teacher, Navigation: Global Navigation Satellite System, Inertial measurement unit, Control Mechanized, Design, Simulation Target & Flying Practical.

3. **Unit III : Electronics Warfare In Communication & Electromagnetic Interference and Electromagnetic Compatibility.**

Electronics Warfare Receiver Design, Direction Finding : Methods and Technology, Electronics Attack : Jamming Technology and Requirement, Electronics Defence : Anti Jamming Technology, Military Electronics Warfare System– Concept & Mitigation Technology, Case Studies : Armoured Fighting Vehicles & Missile Systems.

Reference Books.

1. Mechatronics : Integrated Mechanical Electronic Systems by KP Ramachandran, G K Vijayaraghavan and MS Balasundaram
2. Design of Unmanned Aerial Systems : by Mohammad H Sadraey
3. Engineering Electromagnetic Compatibility : Principles, Measurements, Technologies, and Computer Models by V Prasad Kodali

Text Books.

1. Unmanned Aerial Vehicle Design and Technology: by HikmetKarakoc and EmreOzbek.
2. Electromagnetic Interference and Electromagnetic Compatibility : Principles, Design, Simulation and Applications by L Ashok Kumar and Y Uma Maheswari.
3. Digital Electronics : Principles and Integrated Circuits by Anil K Maini.

Course Objectives.

CO 1 :Understanding Electronic System Design. Students will Learn the principles of designing electronic systems, encompassing both hardware and software components, to meet specific functional requirements.

CO 2 :Exploring Integration Techniques. The course will cover various methods for integrating subsystems, such as vertical and horizontal integration, ensuring seamless communication and operation between components.

CO 3 :Studying Packaging and Physical Integration. An emphasis will be placed on the physical aspects of system integration, including packaging at the chip, board and system levels, to ensure reliability and performance.

Course Outcomes. After completing this Course, the students will be able to:-

CO 1 :Comprehensive Understanding of Electronic Systems. Demonstrate a thorough knowledge of electronic Systems, including their design, functionality and applications across various industries.

CO 2 :Proficiency in Integration Techniques. Apply various integration methods to combine hardware and software components into cohesive electronic systems, ensuring seamless operation and communication between subsystems.

CO 3 :Problem - Solving Abilities. Identify and address challenges in system integration, developing effective solutions to ensure system coherence and functionality.

Course Type **(PC-3)**. - Military Vehicle Propulsion Technology

Course Code. TTC- 503

Unit I : **Dynamic Vehicle Control System, Active and Semi-Active Suspension System, Reduced Acoustic Signature & Low Profile System.**

Real-Time Vehicle Dynamics Monitoring and Adjustment, Integration of Sensors for Detecting Load, Predictive Control Algorithms for Vehicle Stability, Adaptive Damping System for Improved Ride Comfort and Performance, Balancing Vehicle Load Distribution Across Multiple Axles, Impact of Suspension dynamics on vehicle survivability and combat effectiveness. Mechanisms and Components of Active Suspension System, Semi-Active Suspension System and their Control Strategies,

Hydro Pneumatic Suspension Technology in Military Vehicles, Electromagnetic and Magneto Rheological Suspension System, Energy Efficiency and Power Management in Active Suspension System. Acoustic Dampening Technologies in Suspension System for Reducing Noise, Integration of Sound-Absorbing Materials in Suspension Components, Active Noise Cancellation System for Minimizing Acoustic Signature During Movement, Role of Stealth Suspension in Enhancing Survivability in Reconnaissance Operations, Advanced Modelling and Simulation Techniques for Analysing Suspension Noise Reduction, Case Studies of Armoured Fighting Vehicles with Reduced Acoustic Signature Capabilities. Design Principles of Low-Profile Suspension System for Reducing Vehicle Silhouette, Integration of Suspension System with low-profile Armoured Vehicle Design, Impact of Reduced Suspension Height on Vehicle Stability and Maneuverability, Low-Profile Suspension System for Urban and Dense Terrain Combat Scenarios, Use Of Compact Suspension Components to Minimize The Vehicle Radar Cross-Section (RCS) and Advances in Modular Suspension System for Reducing Vehicle Profile while Maintaining Performance.

2. **Unit II : Air Hydraulic Suspension, Electrically Assisted Hydraulics, Energy Harvesting Suspension& Electromagnetic Actuators.** Principles of Air-Hydraulic Suspension System in Military Vehicles, Advantages of Air-Hydraulic System in Adjusting Ride Height and Load-Bearing Capacity, Role of Adaptive Air-Hydraulic Suspension in Improving Off-Road Mobility, Design of Lightweight& High-Pressure Hydraulic Components for Combat Vehicles, Integration of Air-Hydraulic Suspension with Artificial Intelligence -Driven Control System, Case Studies of Hybrid Air-Hydraulic Suspension System in Next-Gen Armoured Fighting Vehicles. Overview of Electrically Assisted Hydraulic System for Vehicle Suspension, Role of Electric Actuators in Enhancing Hydraulic Suspension Performance, Energy Efficiency Improvements with Electrically Assisted Hydraulics in Military Vehicles, Real-Time Electronic Control of Suspension Settings for Different Transaction Reference Number Types, Challenges In Integrating Electric System with Traditional Hydraulics in Harsh Environments, Case Studies of Armoured Fighting Vehicles Utilizing Electrically Assisted Hydraulic Suspension System. Principles of Energy Harvesting in Regenerative Suspension System, Use of Suspension Motion to Generate Electrical Power for on Board System, Materials and

Design Considerations for Energy-Efficient Regenerative Suspensions, Integration of Energy Storage System (Batteries& Capacitors) with Regenerative Suspension, Role of Energy Harvesting in Reducing Overall Vehicle Fuel Consumption, Case Studies of Regenerative Suspension System in Modern Military Platforms. Fundamentals of Electromagnetic Actuators in Military Vehicle Suspension System, Advantages of Electromagnetic Suspension in Providing Smooth, Continuous Ride Adjustment, Role of Magnetic Fields in Supporting Vehicle Load and Improving Ride Comfort, Integration of Electromagnetic Suspension with Artificial Intelligence for Predictive Transaction Reference Number Adjustment, Challenges in Designing Electromagnetic

Actuators for High-Mobility Combat Vehicles, Future Trends in Fully Electromagnetic Suspension System for Tanks and Armoured Fighting Vehicles.

3. **Unit III : Energy Recovery Suspension, Integration of Electric Motors, Continuously Variable Transmission (CVT) & Advanced Drive Terrain System.**

Mechanisms of Energy Recovery in Electromagnetic Suspension System, Design of System for Converting Suspension Movement Into Reusable Electrical Energy, Role of Energy Recovery in Powering on board Electronics and Reducing Engine Load, Integration of Energy Recovery Suspension with Vehicles Power Management System, Applications of Energy Recovery Suspension in Hybrid and Fully Electric Military Vehicles, Future Developments in Combining Energy Recovery Suspension with Autonomous Vehicles Technologies. Design and Placement of Electric Motors in Hybrid Tank Transmission, Torque Blending Between Electric and Traditional Combustion Engines, Power Management Strategies for Hybrid Transmission System, Impact of Electric Motor Integration on Fuel Efficiency and Vehicle Range, Regenerative Energy storage solutions in Hybrid Transmission System, Thermal Management and Cooling of Electric Motors in High-Stress Environments. Working principles of Continuously Variable Transmission in heavy Armoured Vehicles, Efficiency optimization of Continuously Variable Transmissions in low-speed & High-Torque Applications, Materials and Durability Considerations for Military-Grade Continuously Variable Transmissions, Impact of Continuously Variable Transmission on Fuel Efficiency and Vehicles Performance, Integration of Continuously Variable Transmissions in hybrid or fully electric military Vehicles. Modular Drivetrain System for Scalable Vehicles Platforms, Electronic Controls for Dynamic Drivetrain Management, Lightweight Materials for Enhanced Drivetrain Efficiency, Integration of Artificial Intelligence for Predictive Maintenance and Performance, Drivetrain Design for Improved Survivability in Combat.

4. **Unit IV : Energy Distribution System, Terrain Adaptive Transmission, Hybrid Electric Drive, Adaptive Gear Ratios & Regenerative Braking.**

Efficient Distribution of Energy Between Propulsion, on-board System, and Weaponry, Power Electronics and Inverters for Energy Management in Hybrid Transmission System, Smart Grids and Energy Distribution Algorithms for Military Vehicles, Real-Time Energy Monitoring and Load Balancing for Improving Operational Efficiency, Role of Energy Storage (Batteries& Super Capacitors) in Multifunctional Energy System, Impact of Extreme Conditions (Temperature& Humidity) on Energy Distribution System. Adaptive Transmission Technologies for Optimizing Performance Across Different Terrains, Sensor Integration for Real-Time Terrain Assessment And Transmission Adjustment, Transmission Algorithms For Terrain-Specific Torque Distribution

and Gear Shifting, Interaction Between Adaptive Transmission System and Other Vehicles Dynamics (eg, Suspension), Role of Artificial Intelligence and Machine Learning in Predictive Terrain-Based Transmission Control, Case Studies of Terrain-Adaptive Transmission in Modern Armoured Fighting Vehicles. Integrated Control System for Hybrid Electric Vehicles (Hybrid Electric Vehicles), Seamless Transition Between Electric and Combustion Propulsion, Energy Regeneration and Distribution in Hybrid Combat Vehicles, Efficiency Optimisation for Hybrid Electric Combat Vehicles, Combat operational benefits of hybrid electric drives. Mechanisms for Dynamic Gear Ratio Adjustment in Combat Scenarios, Predictive Gear Shifting Based on Terrain and Mission Profile, Performance Impact of Continuously Variable Vs Fixed Gear Ratios, Gear Ratio Optimisation for Fuel Efficiency and Power Output, Artificial Intelligence-Driven Gear Management System for Autonomous Operations. Mechanism of Regenerative Braking in Tracked and Wheeled Military Vehicles, Energy Recovery System in Hybrid Transmission for Increased Efficiency, Role of Regenerative Braking in Reducing Vehicle fuel consumption, Integration with Vehicle Control System for Optimising Energy Recapture, Impact of Terrain on Regenerative Braking Performance in Armoured Fighting Vehicles, Advanced Materials and Components for Enhancing Regenerative Braking Efficiency.

Reference Books.

1. Indian Armoured Corps : History of the Indian Armoured Corps by Colonel SK Malik
2. Defence Technology : Research and Development by Dr Sandeep Jain
3. Mechatronics :Principles and Applications by Godfrey C Omwubola
4. Microgrid Design and operation for Defence and Military application by Michael J Breen
5. Vehicle Propulsion Systems by Lino Guzzella and Antonio Sciarretta.

Text Books.

1. Fundamentals of Propulsion Authored by Dr V Babu
2. A Review work on Suspension Systems models, Control strategies for Suspension System by Nikhil Desai and Bharat Bushan Kale
3. Vehicle Suspension Systems and Electromagnetic Dampers by Saad Kashem, Romesh Nagarajah and Mehran Ektesabi
4. Design and Development of Aerospace Vehicles and Propulsion Systems by S Kishore Kumar, Indira Narayanaswamy, V Ramesh (Editors)

Course Objectives.

CO 1 : Introduction to Military Propulsion Systems. Understand the Significance of Propulsion in military.

CO 2 : Fundamentals of Internal Combustion Engines (ICE) for Military Vehicles. Study engine types (Diesel, Gasoline & Turbine) used in Military Land Vehicles.

CO 3 : Electric and Hybrid Propulsion in Military Vehicles. Evaluate the role of electric and hybrid propulsion in modern warfare.

CO 4 : Thermal and Mechanical Stress Analysis. Study heat dissipation, Cooling mechanisms and material selection.

-Course Outcomes. After completing this Course, the students will be able to :-

CO 1 : Understanding Military Propulsion System. Explain the fundamental principles of propulsion systems in military vehicles.

CO 2 : Performance Analysis. Compare different propulsion technologies based on operational requirements like endurance, mobility and stealth.

CO 3 : Design and Optimization. Apply engineering principles to design and optimize propulsion systems for Military application.

CO 4 : Fuel and Energy Considerations. Understand the logistics and strategic importance of fuel efficiency and supply chain management in military operations.

CO 5 : Emerging Technologies and Future Trends. Explore advancements in hybrid-electric and fully electric propulsion for military Vehicles.

Course Type **(PC-4)**. - Military Vehicle Power Plant

Course Code. - TTC 504

1. **Unit I : Hybrid Engines & Variable Turbine Technology.** Power Distribution between Electric and Combustion Engines, Energy Recovery and Regenerative Braking System, Dual-Mode Propulsion Control System, Optimization of Fuel Efficiency in Hybrid Propulsion, Heat Management and Cooling System in Hybrid Engines. Mechanisms and Benefits of Variable Geometry Turbines (Variable Geometry Turbocharger), Performance Improvement Under Varying Load Conditions, Turbo-Lag Reduction Techniques for Better Responsiveness, Turbine Cooling Techniques in Military Applications & Integrated Turbine-Generator System for Hybrid Vehicles.
2. **Unit II :Fuel Flexibility & Terrain Recognition System.** Multi-Fuel Engines for Battlefield Adaptability, Combustion Optimization for Biofuels and Synthetic Fuels, Engine Calibration for Variable Fuel Properties, Fuel Injection System Designed for Alternative Fuels, Emissions Control Technologies for Cleaner Military Engines. Sensors and Algorithms for Real-Time Terrain Analysis, Artificial Intelligence Integration for Adaptive Vehicle Responses Based on Terrain, Terrain Classification and its effect on Vehicle Propulsion, Autonomous Mobility Solutions Using Terrain Recognition Data & Role of Terrain Recognition in Improving Fuel Efficiency.
3. **Unit III :Fully Electric Armoured Fighting Vehicles & Turbojets.** Battery Technology and Energy Density for Military Applications, Electric Motor Configurations for Tracked Vs Wheeled Vehicles, Energy Storage and Fast-Charging Infrastructure for Electric Armoured Fighting Vehicles, Performance Trade-Offs Between Range and Combat Capability, Silent running (stealth) capabilities in electric Armoured Fighting Vehicles. Turbojet Propulsion in High-Speed, Lightweight Military Platforms, Advantages and Limitations of Turbojet Engines in Military Vehicles, Cooling System for Turbojet Engines Under Combat Conditions, Fuel Efficiency Optimization for Turbojet - Powered Vehicles & Turbojet Integration with Hybrid Electric System.
4. **Unit IV : Advanced Ceramic Matrix Composites (CMC) & Hybrid Electric Turbine System.** Benefits of Ceramic Matrix Composites in High-Temperature Engines, Durability and Weight Reduction Using Advanced Materials, Thermal Resistance of Composites in Turbine Applications, Material Failure Modes and their Implications for Engine Design, Cost-Benefit Analysis of Using Composites in Military Engines. Energy Recovery System Integrated with Turbine Engines, Electric Power Generation Via Turbine Exhaust Heat, Advanced Control System for Hybrid Electric Turbine Vehicles, Fuel Efficiency Benefits of Hybrid Electric Turbine System & Tactical Advantages of Hybrid Electric Turbine - Driven Vehicles.

5. **Unit V : High Performance Heat Exchangers & Thermal Barrier Coatings.**

Materials and Design for Maximizing Heat Transfer Efficiency in Military Vehicles, Lightweight, Corrosion-Resistant Materials for Durable Heat Exchangers, Microchannel Heat Exchangers for Compact Military Applications, Heat Exchanger Design for Extreme Temperature Variations in Combat, Optimization of Heat Exchangers for Reducing Power Consumption, Computational Fluid Dynamics (CFD) Tools for Designing Advanced Heat Exchangers. Materials Science of Thermal Barrier Coatings for High-Temperature Components, Application Methods for Thermal Barrier Coatings in Military Engines and System, Durability and Erosion Resistance of Thermal Barrier Coatings in Combat, Role of Coatings in Enhancing Heat Resistance and Reducing Thermal Stress, Nanotechnology Applications in Developing Advanced Thermal Barrier Coatings & Case Studies of Thermal Barrier Coatings for Improving Vehicle Longevity in Harsh Environments.

6. **Unit VI : Synthetic Oils, Bio-Based Lubricants & Automatic Distribution.**

Properties of Synthetic Oils and their advantages over Conventional Oils in Military Applications, High-Temperature Stability and Oxidation Resistance in Synthetic Oils For Extreme Environments, Formulation of Synthetic Oils for Specific Military Applications (Engine, Transmission, Gear System etc), Compatibility of Synthetic Lubricants with Modern Composite and Metallic Materials used in Tanks, Performance of Synthetic Oils in Extreme Cold and Hot Climates, Enhancing Operational Readiness, Trends in Synthetic Oil Development for Fuel Economy and Radiation Wear in High-Performance Engines. Overview of Bio-Based Lubricants and their Environmental Benefits in Military Vehicles, Performance Comparison Between Bio-Based and Synthetic Lubricants Under Combat Conditions, Formulation and Properties of Bio-Based Oils For High-Load Military System, Challenges and Advancements in improving the Stability and Longevity of Bio-Based Lubricants, Role of Bio-Lubricants in Reducing the Environmental Impact of Military Operations, Case Studies of Bio-based Lubricants being Trial Evaluated in Military Fleets. Working Principles of Automated Lubrication System in Military Vehicles, Design of Centralized Lubrication System for Continuous, Real-Time Distribution Across Critical Components, Role of Automatic Distribution in Reducing Maintenance Frequency and Extending Component Life, Types of Lubricants Used in Automated System and their Suitability for High-Performance Armoured Fighting Vehicles, Advances in Sensors for Detecting Lubrication needs and Triggering Automatic Distribution & Case Studies of Automatic Lubrication System in Combat Scenarios.

7. **Unit VII : Artificial Intelligence Driven Smart Lubrication System & Combined Lubrication and Cooling.**

Integration of Artificial Intelligence for Predictive Lubrication Needs Based On Real-Time Operational Data, Machine Learning Algorithms for Analyzing Vehicles Performance and Adjusting Lubrication Parameters, Artificial Intelligence-Driven Self-Diagnostic System for Identifying Lubrication Issues before Mechanical Failure, Role of Artificial Intelligence in Minimizing Lubricant Waste while Ensuring Optimal Performance in Combat

Conditions, Challenges and Solutions in Deploying Artificial Intelligence-Driven Lubrication in Remote or Extreme Environments, Future Trends in Fully Autonomous Artificial Intelligence - Driven Lubrication System for Armoured Fighting Vehicles. Dual - Function Lubricants Designed to Provide both Cooling and Lubrication in High-Stress Components Heat Dissipation Mechanisms of Lubricants in Modern Power Terrain and Transmissions, Material

Compatibility Challenges with Multifunctional Lubricants in Military-Grade Components, Impact of Combined Lubrication and Cooling on Enhancing Vehicle Performance in Extreme Conditions, Integration of Multifunctional Lubrication System with Onboard Vehicle Diagnostics & Case Studies of Combined Lubrication and Cooling System in Next-Generation Military Vehicles.

7. **Unit VIII : Cross-System Lubrication & Micro-Encapsulation Technology.**

Design of Lubrication System that Service Multiple Components (Engine, Gearbox, Suspension etc), Role of Cross-System Lubrication in Simplifying Maintenance and Reducing Overall Lubricant Consumption, Challenges of Ensuring Proper Lubricant Flow and Pressure across different Vehicle Sub System, Advances in Cross-System Lubrication for Hybrid and Fully Electric Military Vehicles, Interaction Between Cross-System Lubrication and Automated Distribution System, Case Studies of Cross-System Lubrication Applications in Armoured Fighting Vehicles. Principles of Micro-Encapsulation Technology for Self-Healing Lubricants in Military Applications Types of Micro-Capsules used for Delivering Repair Agents in Lubrication System, Mechanisms by Which Self-Healing Lubricants respond to Wear and Restore Functionality, Advantages of Self-Healing Lubricants in Reducing Downtime and Maintenance Needs in Combat Vehicles, Future Developments in Self-Healing Lubrication Materials for Extended Durability in Extreme Conditions & Case Studies of Self-Healing Lubricants in Advanced Military Vehicles.

8.

Reference Books.

1. Electric & Hybrid Vehicles, Second Edition by A K Babu
2. First Fuel : India's Energy efficiency Journey and a Radical Vision for Sustainability by Padupadmanabhan.
3. Handbook of advanced Ceramics and Composites : Defence, Security, Aerospace and energy application by Roy Johnson and Yashwant, R Mahajan.
4. Jet Engines by Jaganathan and Jain.
5. Heat Transfer : Principles and Applications by Binay K Dutta.

6. Design of Thermal Barrier Coatings- A Modelling Approach by Mohit Gupta
7. Concept of Automatic Lubrication System and Comparison with Conventional Lubrication System by International Journal of Engineering Research & Technology.
8. Automotive Fuel, Lubricating and Cooling System by William H Crouse, Donald L Anglin
9. Functional Coatings : By Polymer Microencapsulation by Swapan Kumar Ghosh

Text Books.

1. Methanol : A Sustainable Transport Fuel for Engines by Avinash Kumar Agarwal
2. Internal Combustion Engines by V Ganesan
3. Bio fuels Engineering Process Technology by Caye M Drapcho
4. Electric and Hybrid Vehicles Technologies, Modelling and Control A mechatronic Approach by Amir Khajepour, M Saberfallah, AvestaGoodarzi
5. Ceramic Matrix Composite by Narottam P Bansal, J P Singh
6. Fundamental of Heat Exchanger Design by Ramesh K Shah& Dusan P Sekulie
7. Automated Continuous Process Control by A Smith
8. Synthetic Lubrication and HighPerformance Functional Fluids by Leslie R Rudnik& Ronald I Shabkin

Course Objectives.

CO 1 : Understanding Power Plant Fundamentals. Compare different power plant types (diesel, hybrid, electric and gas turbine) in vehicle propulsion.

CO 2 : Design and Performance Characteristics. Study the impact of environmental conditions (temperature, altitude, terrain etc) on engine performance.

CO 3 : Components and Systems : Identify Key Engine Components. Fuel System, Cooling System, Lubrication Systems and Exhaust System.

CO 4 :Maintenance and Troubleshooting. Develop skills in diagnosing and repairing common engine problems.

CO 5 :Fuel and Energy Considerations. Evaluate different fuel types used in military engines (diesel, JP-8& alternative fuels).

CO 6 :Technological Advancements. Study advancements in fuel cells and alternative power sources for military vehicles.

CO 7 :Field Applications and Tactical Considerations. Understand the role of power plants in mobility, operational range and combat readiness.

Course Outcomes. After completing this Course, the students will be able to:-

CO 1 :Knowledge and Understanding. Identify and describe key components of military vehicle power plants, including fuel, cooling, lubrication and exhaust systems.

CO 2 :Technical Skills. Diagnose and troubleshoot common issues in military vehicle power plant.

CO 3 :Practical Application. Assess fuel efficiency and power-to-weight ratios to determine the best engine choice for specific military applications.

CO 4:Technological and Strategic Awareness. Compare conventional military power plants with emerging hybrid, electric and alternative fuel technologies.

CO 5 : Evaluate future trends in military vehicle propulsion and their implications for defence strategies.

Course Type (LAB) - Syndicate Technical Studies

Course Code - TTC 505

1. **Unit 1 : Fundamentals of Technical Studies.** A small-group method of teaching student officers which encourages innovation and gives experience of tackling design problems.

2. **Unit 2 : Synergised Syndicate Implementation.** Emphasises the importance of co-ordinated group activity. Helps the development of communicative skills and gives opportunities for exercising judgement and decision making.

3. **Unit 3 : Benefits of Syndicate Technical Studies.** Advantages of gaining excellent student motivation and assisting a closer liaison with the engineering industry. Develop ability to integrate knowledge, work collaboratively and apply technical skills to real-world problems.

Reference Books.

1. "Effective Project Management: Traditional, Agile, Extreme" by Robert K Wysocki
2. "Project Management Body of Knowledge (PMBOK Guide)" by Project Management Institute

Text Books.

1. "Project Management in Practice" by Mantel, Meredith, Shafer and Sutton
2. "Software Project Management: A Process-Driven Approach" by Ashfaq Ahmed

Course Objectives

CO 1: Integrate Technical Knowledge. Integrate technical knowledge from various disciplines to solve complex problems and demonstrating the ability to think holistically.

CO 2 :Develop Collaborative Skills. Develop effective collaborative skills, working in syndicates to share knowledge, expertise and resources to achieve common goals.

CO 3 :Analyze Real-World Scenarios. Analyze real-world scenarios, case studies or industry problems and demonstrating the ability to apply theoretical knowledge to practical situations.

CO 4 :Design and Propose Solutions. Design and propose innovative solutions to complex technical problems and demonstrating the ability to think creatively and critically.

CO 5 :Communicate Technical Proposals. Communicate technical proposals and solutions effectively to both technical and non-technical stakeholders and demonstrating the ability to present complex ideas clearly.

Course Outcomes.

CO 1: Demonstrated Integrated Technical Knowledge. Students will be able to demonstrate a deep understanding of how technical knowledge from various disciplines can be integrated to solve complex problems.

CO 2 : Developed Effective Collaboration Skills. Students will be able to work effectively in teams, sharing knowledge, expertise and resources to achieve common goals.

CO 3 : Analyzed and Solve Real-World Problems. Students will be able to analyze real-world scenarios, case studies or industry problems and develop innovative solutions.

CO 4 : Designed and Proposed Innovative Solutions. Students will be able to design and propose innovative solutions to complex technical problems, demonstrating creativity and critical thinking.

CO 5 : Effectively Communicated Technical Proposals. Students will be able to communicate technical proposals and solutions clearly and effectively to both technical and non-technical stakeholders.

Course Type (PGC). - Missile System Technology & Its Designing

Course Code. - TTC 506

1. **Unit I : Missile System.** Missile Types and Capabilities, Launch Platforms and Mechanisms, Data Link and Guidance System, Multi Mission Capabilities, Control System, Target Seekers, Top Attack Technology, Anti Jamming Measures, Target Software Capabilities, Control Polar, Smart Warheads, Triple Tandem Warheads, Anti Armour protection System Measures & Aero foil Design.

Reference Books.

1. Fundamentals of Guided Missiles by M K Venkataraman
2. Introduction to modern Missile Guidance by Rafael Yanushevsky

Text Books.

1. Missile Guidance and Control Systems by N S Nagaraja
2. Advanced Missile Technology by Ashish Tewari

3. Integrated Guided Missile Development Programme (IGMDP) : India's Success Story by Dr G Satheesh Reddy

Course Objectives.

CO 1 : Introduction to Missile Systems. Explain the fundamental principles of missile technology.

CO 2 : Missile Components and Functionality. Describe the key components of a missile (Warhead, propulsion, guidance, control, etc).

CO 3 : Missile Guidance and Control. Explain different missile guidance techniques (command, homing, inertial, etc).

CO 4 : Missile System Integration and Testing. Explain the procedures for missile testing and validation.

CO 5 : Safety and Reliability in Missile Systems. Explain safety protocols for missile handling, storage, and launch.

Course Outcomes. After completing this Course, the students will be able to:-

CO 1 : Fundamental Understanding. Demonstrate a comprehensive understanding of missile system principles and classifications.

CO 2 : Missile Components and Design. Identify and describe the key components of a missile, including propulsion, warhead, guidance and control systems.

CO 3 : Guidance, Navigation, and Control. Evaluate the effectiveness of different navigation and targeting techniques.

SEMESTER – II

Course Type (PC-5).- Autonomous Unmanned Ground Vehicles - I

Course Code. - TTC 507

1. Unit I : Reinforcement Learning for Dynamic Decision Making.

Introduction to Reinforcement Learning (RL) for Autonomous Navigation in Combat Environments, Deep RL Algorithms for Real-Time Decision-Making in Unpredictable Military Scenarios, Application of RL in Obstacle Avoidance and Tactical Movement In

High-Threat Zones, Role of RL in Optimizing Unmanned Ground Vehicles Mission Success through Continuous Learning from Battlefield Data, Integration of RL with onboard System for Dynamic Adaptation to New Terrain and Threats, Case Studies of Unmanned Ground Vehicles Employing RL for Mission-Critical Decision-Making.

2. **Unit II : Simultaneous Localization and Mapping (SLAM).**

Fundamentals of Simultaneous Localization and Mapping algorithms for real-time Unmanned Ground Vehicle navigation and mapping in uncharted territories, Use of Simultaneous Localization and Mapping for enhancing Unmanned Ground Vehicles situational awareness in urban and off-road environments, Integration of Vision-Based Simultaneous Localization and Mapping with Light Detection and Ranging and Radar System for Robust Positioning, Advances in Simultaneous Localization and Mapping Technology for Autonomous Indoor and Underground Operations, Fusion of Simultaneous Localization and Mapping Data With Artificial Intelligence for Improved Decision-Making and Target Identification, Case Studies of Simultaneous Localization and Mapping Implementation in Military Unmanned Ground Vehicles for Real-Time Reconnaissance.

3. **Unit III : Autonomous Swarm Configuration.**

Principles of Swarm Robotics and their applications in Military Unmanned Ground Vehicle Operations, Artificial Intelligence Algorithms for Managing Swarm Coordination and Communication in Combat Missions, Distributed Control Strategies for Autonomous Unmanned Ground Vehicle Swarms in Reconnaissance and Search-and-Rescue, Swarm Intelligence for Dynamic Target Tracking and Coordinated Assault Tactics, Integration of Aerial and Ground Swarm Units for Multi-Domain Operational Effectiveness, Case Studies of Swarm Unmanned Ground Vehicle Operations in Defence Scenarios.

4. **Unit IV : Multispectral and Hyper Spectral Imagery.**

Role of Multispectral Imaging in Unmanned Ground Vehicle Target Recognition and Terrain Analysis. Application of Hyperspectral Sensors for Detecting Hidden Threats (IEDS, Mines, Camouflaged Enemies etc), Integration of Spectral Data with Artificial Intelligence System for Real-Time Battlefield Intelligence, Use of Hyperspectral Sensors in Environmental Monitoring and Chemical Detection, Advances in Miniaturizing Multispectral and Hyperspectral System for Unmanned Ground Vehicle Deployment, Case Studies of Spectral Imaging in Unmanned Ground Vehicle Combat and Reconnaissance Missions.

5. **Unit V : Radar and Sonar System.**

Overview of Radar System for Unmanned Ground Vehicles Navigation in Low-Visibility Conditions, Use of Sonar for Underwater and Subterranean Unmanned Ground Vehicles Operations (eg, Tunnel Detection), Role of Radar and Sonar in Detecting Moving Targets and Obstacles in Complex Terrain, Integration of Radar and Sonar with Sensor Fusion System for Enhanced Situational Awareness, Challenges in Deploying Radar and Sonar in Compact Unmanned Ground Vehicles and Armoured Fighting Vehicles, Case Studies of Radar and Sonar System in Unmanned Ground Vehicles for Counter-Insurgency Operations.

6. **Unit VI : Chemical and Biological Detection System** Role of Chemical Sensors in Detecting Hazardous Agents (Chemical Warfare& Toxic Industrial Chemicals etc), Integration of Biological Detection System for Early Identification of Biological Threats, Artificial Intelligence-Enhanced Sensor Fusion for Real-Time Chemical and Biological Threat Detection, Use of Multi Sensor Data Fusion to Improve Detection Accuracy and Reduce False Positives, Advances in Portable Chemical and Biological Sensors for Unmanned Ground Vehicle Deployment in Contaminated Zones, Case Studies of Unmanned Ground Vehicles with Chemical and Biological Detection Capabilities in Military Operations.

7. **Unit VII : Unamend Ground Vehicles and Aerial Hybrid Systems** Design and Operational Benefits of Unmanned Ground Vehicle-Aerial Hybrid System for Multi-Domain Warfare, Communication and Control Integration between Unmanned Ground Vehicles and Autonomous Drones for Coordinated Missions, Role of Unmanned Ground Vehicle-Aerial Hybrids in Enhancing Situational Awareness and Tactical Flexibility, Future Trends in Combined Unmanned Ground Vehicles and Aerial System for Surveillance and Assault Roles, Artificial Intelligence Algorithms for Managing Coordinated Unmanned Ground Vehicle-Aerial Hybrid Formations, Case Studies of Unmanned Ground Vehicles and Aerial Hybrid System in Battlefield Reconnaissance and Strike Missions.

Reference Books.

1. Intelligent Unmanned Ground Vehicles Edited by Martial H Hebert, Charles Thorpe, Anthony Stentz
2. Deep Attention Driven Reinforcement Learning (DAD-RL) for Autonomous Decision-Making in Dynamic Environments by Jayabrata Chowdhury
3. Radar Principles by NadavLevanon

Reference Books.

1. **RAKSHAK - The Multipurpose Unmanned Ground Vehicle** - this publication introduces 'RAKSHK', a four-wheel-drive UGV capable of performing various tasks in both autonomous and remote control modes, highlighting its applications in defence scenarios.
2. **Multispectral and Hyperspectral Imaging : Principles and Application** "This publication reviews state-of-the-art algorithmic approaches addressing practical challenges in hyperspectral image analysis, covering a diverse array of application".

Course Objectives.

CO 1: Introduction to Unmanned Ground Vehicles. Understand the fundamental principles of unmanned ground vehicles.

CO 2 : Vehicle Dynamics and Control. Study the kinematics and dynamics of mobile robots.

CO 3: Perception and Sensor Fusion. Understand sensor fusion techniques for robust environmental perception.

Course Outcomes.

CO 1 : Design and develop control systems for autonomous Unmanned Ground Vehicles.

CO 2 : Implement sensor fusion techniques for perception and navigation.

CO 3 : Develop Artificial Intelligence-driven decision-making algorithms for autonomous operations.

CO 4 : Apply knowledge to real-world autonomous vehicles projects.

Course Type (PC-6). - Armoured Fighting Vehicle Technology

Course Code. - TTC 508

1. **Unit I : Onboard Power Generation & High-Performance Elastomers, Silicon Rubber and Fluorinated - Elastomers.**

Auxiliary Power Units (Accelerated Processing Units) for on Board Electronics, Energy Harvesting Technologies (eg Solar, Kinetic etc), Power Management System for Electronic Warfare and C4ISR, Integration of Renewable Energy Sources in Military Vehicles, Fuel Cell Technology for Sustained Power Generation. Properties of High-

Performance Elastomers for Seals and Gaskets in Military-Grade Components, Resistance to Extreme Temperatures and Chemical Exposure in Silicone Rubbers and Fluorinated -Elastomers, Role of Elastomers in Maintaining System Integrity under High Vibration and Pressure Conditions, Development of Elastomers with Enhanced Longevity for Critical Sealing Applications in Tanks and Armoured Fighting Vehicles, Advances in Fluorinated Elastomers for Fuel and Lubricant Resistance in Modern Military Vehicles, Case Studies of Elastomers in High-Performance Military Vehicle Applications.

2. **Unit II : Composite Rubber Materials & 3D Printing of Rubber Parts.**

Development of Composite Rubber Materials Combining Elastomers with Reinforcements for Improved Durability, Applications of Composite Rubbers in Tracked Vehicle Suspension System and other High-Stress Areas, Material Innovations in Composite Rubbers for Impact Resistance and Load Distribution, Use of Composite Rubbers in Military Vehicle Armoured System for Energy Absorption, Future Trends in Developing Lightweight, High-Performance Composite Rubber Materials, Case Studies of Composite Rubbers in Military Vehicle Construction and Operation. Applications of 3D Printing Technology for Manufacturing Rubber Components in Military Vehicles, Advances in 3D Printing Materials for Producing High-Strength, Custom-Designed Rubber Parts, Benefits of Additive Manufacturing for Rapid Prototyping and Field-Replaceable Components, Challenges in Maintaining Material Integrity and Performance in 3D-Printed Rubber Parts, Role of 3D Printing in Reducing Supply Chain Dependency for Critical Rubber Components & Case studies of 3D-printed Rubber Parts in Modern Military Platforms.

3. **Unit III : Advanced Torque Management System, Hydrostatic & Electric Drive and Adaptive Control System.**

Adaptive Torque Distribution for Varying Terrain Conditions, Torque Vectoring System for Enhanced Maneuverability, Real-Time Torque Modulation for Hybrid/Electric Drives, Integration of Artificial Intelligence in Torque Management System, Predictive Torque Control for Autonomous Vehicle. Principles of Hydrostatic Transmissions in Military Vehicle, Comparative Analysis of Hydrostatic vs Mechanical Drive System, Advantages of Electric Drive System in Tracked Vehicles, Hybrid Hydrostatic-Electric Drive System for Better Efficiency, Modular drive units for flexible Vehicle designs. Role of Artificial Intelligence in Dynamic Control and Real-Time Decision-Making, Machine learning algorithms for predicting Terrain conditions, Self-learning System for optimal Vehicle performance in

varying conditions, Vehicle attitude adjustment in response to external inputs (Terrain, obstacles etc), Integration of Artificial Intelligence with Electronic Stability Control (ESC) System, Artificial Intelligence-driven predictive maintenance for Vehicle Dynamics System.

4. **Unit IV : Integration of Radars in Armoured Fighting Vehicles, Obstacle Detection & Avoidance System and Hydraulic & Pneumatic System.**

Radar-Based Detection of Terrain Hazards and Landmines, Synthetic Aperture Radar (SAR) and Ground-Penetrating Radar (GPR) Technologies, Integration of Radar System with Vehicle Control System, Data Fusion from Radar and other Sensors for Obstacle Detection, Real-Time Terrain Mapping Using Radar System, Impact of Radar-Based Detection System on Vehicle Maneuverability and Safety. Sensor Types and Technologies for Obstacle Detection (Light Detection and Ranging, Radar, cameras etc), Artificial Intelligence Algorithms for Obstacle Classification and Threat Assessment, Autonomous Obstacle Avoidance System for Military Vehicles, Role of Computer Vision in Real-Time Obstacle Detection, Vehicle-to-Infrastructure (V2I) Communication for Obstacle Warning System, Integration of Obstacle Detection with Vehicle Control and Navigation System. Fundamentals of Hydraulic and Pneumatic System in Track Tensioning, Real-Time Track Tension Adjustment for Varying Terrain Conditions, Design and Components of Hydraulic Track Tensioning System, Pneumatic Track Tensioning System and their Advantages, Maintenance and Durability of Hydraulic Vs Pneumatic System, Energy Efficiency of Hydraulic and Pneumatic System in Armoured Fighting Vehicles.

5. **Unit V : Smart Actuators, Sensor Integration & Composite Materials.**

Role of Smart Actuators in Dynamic Track Tension Control, Materials and Designs for Lightweight and High-Performance Actuators, Integration of Smart Actuators with Vehicle Control System, Real-Time Feedback and Adjustment System in Smart Actuators, Power Requirements and Energy Efficiency of Smart Actuators, Failure Modes and Redundancy in Smart Actuator System. Sensor Types for Monitoring Track Tension and Vehicle -Terrain Interaction, Integration of Strain Gauges, Accelerometer and Proximity Sensors, Role of Sensor Data in Real-Time Track Tensioning Control, Sensor Networks and Communication Protocols in Military Vehicles, Environmental Factors Affecting Sensor Performance in Combat Scenarios, Artificial Intelligence-Driven Analysis of Sensor Data for Proactive Adjustments. Types of Composite Materials used in Military Vehicle Dynamics (eg Carbon Fibre, Kevlar etc), Weight Reduction Techniques using Advanced Composites, Durability and Impact Resistance of Composites in Combat Environments, Design and Manufacturing Processes for Composite Structures, Thermal Properties of Composites in High-Stress Applications & Cost-benefit analysis of composites vs Traditional materials.

6. **Unit VI : Aluminum and Titanium Alloys, Mobility Maps & Track Design for Tracked Vehicles.** Characteristics of Aluminum Alloys used in Military Vehicles, Titanium Alloys for High-Strength, Lightweight Applications, Corrosion Resistance and Fatigue Life of Aluminum and Titanium Alloys, Fabrication and Welding Techniques for Aluminum and Titanium Structures, Comparison of Weight and Strength Benefits between Alloys and Composites, Use of Hybrid Materials Combining Alloys and Composites for Optimized Performance. Creating Mobility Maps for different Terrains in Types (Sand, Mud, Snow etc), Role of Mobility Maps in Mission Planning and

Vehicle Routing, Artificial Intelligence-Driven Updates to Mobility Maps Based on Real-Time data, Historical data analysis for Terrains in prediction and Vehicle adaptation, Mobility Index Calculation and its impact on Vehicle Performance, Simulation Tools for Creating and Updating Mobility Maps. Track Materials and Design for Optimal Terrains in Interaction, Role of Track Width and Length in Vehicle Mobility and Stability, Suspension Design Considerations for Improving Tracked Vehicle Performance, Impact of Track Design on Vehicle Weight Distribution and Ground Pressure, Tracks for Multi-Antenna Capability (eg Sand, Rocks, Forest etc) & Maintenance and Lifecycle Management of Military Vehicle Tracks.

7. **Unit VII : Simulation Tools for Vehicles Terrain in Interaction, Vapour Compression System & Heat Pipes.** Simulation Models for Predicting Vehicle Performance on Different Terrains, Use of Digital Twins in Terrain Mechanics Simulation, Artificial Intelligence-Driven Simulations for Real-Time Vehicle Adaptation, Predictive Models for Terrain Impact on Vehicle Stability and Dynamics, Integration of Simulation Tools with Control System for Proactive Adjustments, Role of Virtual Testing Environments in Vehicle-Terrain Interaction Analysis. Working Principles of Vapour Compression in High-Performance Cooling, Components of Vapour Compression System: Compressor, Condenser, Evaporator, Refrigerants used in Military-Grade Cooling System and Environmental Impact, Optimization Techniques for Energy-Efficient Vapour Compression System, Integration of Vapour Compression System with Vehicle Electronics and Powertrain, Maintenance and troubleshooting of Vapour compression System in Harsh Conditions. Mechanisms of Heat Transfer in Heat Pipes for Military Applications, Materials used in Heat Pipes and their impact on Thermal Conductivity, Design Considerations for Heat Pipes in High-Temperature Environments, Integration of Heat Pipes in Compact Military Vehicle System, Passive Vs Active Heat Pipe System for different Cooling Needs and Advancement in Micro & Nanotechnology for Enhancing Heat Pipe Performance.

8. **Unit VIII : Solid State Cooling, Energy Harvesting & Artificial Intelligence-Driven Thermal Management System.** Fundamentals of Thermoelectric Effect and its Application in Cooling System, Peltier Devices and their Role in Solid-State Cooling, Efficiency of Solid-State Cooling Compared to Traditional Methods, Materials for improving the thermoelectric figure of merit (ZT), Integration of solid-state cooling with Vehicle electronics for localized cooling, Durability and reliability of solid-state cooling in extreme military environments. Thermoelectric Energy Harvesting Principles in Military Vehicles, Integration of Energy Harvesting System with Cooling for Increased Efficiency, Role of Energy Harvesting in Powering on Board Electronics and Sensors, Thermal-to-Electric Energy Conversion for Hybrid Cooling-Power System, Advancements in Materials for Enhancing Energy Harvesting Efficiency, Applications of Energy Harvesting in Reducing the Vehicles Energy Footprint. Role of Artificial Intelligence in Optimizing Real-Time Thermal Management in Military Vehicles, Predictive Cooling Algorithms Based on operational Parameters, learning for Dynamic Adjustment of Cooling System Based on Mission Profiles, Integration of Artificial Intelligence with Sensors for Proactive Temperature Control, Autonomous Control of Cooling System for enhancing System longevity & Case studies of Artificial Intelligence-driven thermal Management in Modern Military Platforms.

9. **Unit IX : Adaptive Pumps, Drive-by-Wire & Advanced Driver Assistance System.** Variable-Speed Pumps for Dynamic Cooling Requirements, Energy-Efficient Design and Control of Adaptive Pumps in Vehicle Cooling, Integration of Sensors for Real-Time Adjustment of Pump Performance, Smart Pumps with Feedback System for Adjusting Flow Rates, Artificial Intelligence Integration with Adaptive Pumps for Precise Thermal Management, Maintenance and Monitoring System for Ensuring Adaptive Pump Reliability. Fundamentals of Drive-by-Wire Technology in Military Vehicles, Advantages of Removing Mechanical Linkages for Steering and Braking System, Fail-Safe Mechanisms and Redundancy in Drive-by-Wire System for Combat Vehicles, Impact of Drive-by-Wire on Vehicle Maneuverability and Precision Control, Challenges and Solutions in Electronic Vehicle Control System, Case Studies of Drive-by-Wire Integration in Modern Military Vehicles. Sensor Technologies for (ADAS) in Military Vehicles (LIDAR, Radar, Cameras etc), Role of ADAS in Improving Driver Safety and Reducing Workload in Combat Situations, Adaptive Cruise Control and Automated Braking for Tracked Vehicles, Obstacle Detection and Avoidance System Integrated with ADAS, Integration of ADAS with Autonomous and Semi-Autonomous Tank Operations, Challenges of Implementing ADAS in off-road, Rugged Terrain Environments.

Reference Books.

1. Modern Tanks and Armoured Fighting Vehicles: Their Design and Development by Anthony Tucker-Jones
2. Tank : The Definitive Visual History of Armored Vehicles by DK Publishing
3. Science and Technology of Rubber by James E Mark, Burak Erman & Mike Roland
4. 3D Printing of Polymers : Fundamentals, Materials and Application Edited by Patrick J Smith
5. Vehicle Dynamics and Control by Rajesh Rajamani
6. Electric and Hybrid Vehicles : Design Fundamentals by Iqbal Husain
7. Sensor Systems : Fundamentals And Application by Clarence W De Silva
8. Theory of Ground vehicles by J Y Wong
9. Aluminium Alloys : Structure and Properties by L F Mondolfo
10. CAN-based Simulator design for Vehicles by S S Dorle & S S Gawande
11. A Review on Application of Heat Pipe to Improve Vapor Compression Refrigeration System Performance by Sudhanshu Sharma, Bobby Singh, Aryan Raj, Abhishek Kumar Maurya & Darshan

12. Autonomous Driving and Advanced Driver- Assistance Systems(ADAS) by Lentin Joseph Amit Kumar Mondal

Text Books.

1. Armored Fighting Vehicles (AFV) Technical Manual by Major (Retd) R William Orr
2. Rubber Technology : Two Volume Set by SC Bhatia and Avishek Goel
3. Polymer Science and Technology : Plastics, Rubbers Blends and composites by Dr Premamoy Ghosh
4. A Text Book of Hydrostatics by Dr M Ray
5. Combat Net Radio MK-II for Armoured Fighting Vehicle by Bharat Electronics Limited
6. Smart Material Systems and MEMS : Design and Development Methodologies by Vijay K Varadan, K J Vinoy, S Gopalakrishnan
7. Aerospace Materials and Material Technologies : Volume 1 : Aerospace Materials by N Eswara Prasad and R J H Wanhill
8. A Review on Application of Heat Pipe to Improve vapor compression Refrigeration System performance by Publisher : Springer Professional
9. Advances in Solar Power Generation and Energy Harvesting : Select Proceedings of ICEPGEC 2019 Editors by Vinod Kumar Jain, S Arumugam& S Srirambabu
10. Fault Tolerant Drive By Wire Systems : Impact on Vehicle Safety and Reliability by Sohail Anwar

Course Objectives.

CO 1 :Understanding Fundamentals. Gain a comprehensive understanding of the fundamental principles of Armoured Fighting Vehicle (AFV) armament systems.

CO 2 :System Components. Learn about the various components of AFV armament, including guns, ammunition, targeting systems and fire control systems.

CO 3 :Technological Developments. Explore the latest technological advancements in Armoured Fighting Vehicle armament and their impact on combat effectiveness.

CO 4 :Design and Function. Study the design, function and operational aspects of different Armoured Fighting Vehicle armament systems.

CO 5 :Integration. Understand how armament systems are integrated into Armoured Fighting Vehicles and the considerations for their effective deployment.

CO 6 :Performance Analysis. Analyze the performance characteristics and capabilities of different Armoured Fighting Vehicle armament systems.

CO 7 :Maintenance and Troubleshooting. Learn the basics of maintaining and troubleshooting Armoured Fighting Vehicle armament systems.

CO 8 :Operational Tactics. Understand the tactical employment of Armoured Fighting Vehicles with respect to their armament in various combat scenarios.

CO 9 :Safety and Regulations. Familiarise with safety protocols and regulatory requirements related to the operation and maintenance of Armoured Fighting Vehicle armament systems.

CO 10 :Historical Context. Study the historical development of Armoured Fighting Vehicle armament technology and its evolution over time.

CO 11 :Future Trends. Explore future trends and potential innovations in Armoured Fighting Vehicle armament technology.

Course Outcomes. After completing this Course, the students will be able to:-

CO 1 :Knowledge Application. Ability to apply fundamental principles and concepts of Armoured Fighting Vehicle armament technology in practical scenarios.

CO 2 :Component Identification. Proficiency in identifying and explaining the functions of various components of Armoured Fighting Vehicle armament systems.

CO 3 :Technological Proficiency. Enhanced understanding of current technological advancements and their applications in Armoured Fighting Vehicle armament.

CO 4 :Design Evaluation. Capability to evaluate and critique the design and operational effectiveness of different Armoured Fighting Vehicle armament systems.

CO 5 :Integration Skills. Skills to effectively integrate armament systems into Armoured Fighting Vehicles and considering operational requirements & constraints.

CO 6 :Performance Assessment. Ability to assess and compare the performance characteristics of various Armoured Fighting Vehicle armament systems.

CO 7 :Maintenance Competence. Competence in maintaining, troubleshooting and ensuring the operational readiness of Armoured Fighting Vehicle armament systems.

Course Type (PE-I). - Explosives & Designing

Course Code. - TTC 509

1. **Unit I : High Explosives.** Explosive Formulations, Detonation Dynamics, Fragmentation Technology, Low Vulnerability Explosive, Smart Munitions, Enhancing Energy of Explosives, Binding Materials, Ignition System, Coolant Technology& Safety Mechanical and fuzes.

2. **Unit II : Kinetic Energy Ammunition.** Penetrator Material Technology, Sabot Material, FIN Technology, Ballistic Performance Analysis, Muzzle Velocity Optimisation, Guided Kinetic Energy Technology, Depleted Uranium Penetrator& Hydrodynamic Flow.

3. **Unit III : Propellant Technology.** Burning Rate Controlled, Storage and stabilization, Web Size Optimisation, Granule design, Chain of Explosive, Adaptive Charge Technology, Caseless Ammunition& Liquid Propellant Technology.

4. **Unit IV : Ammunition Stowage and Loading.** Ammunition Ergonomics and Accessibility, Weight Distribution and balancing, Robotic Autoloaders, Bustle autoloaders, Blast off Panel Design, Ammunition Recognition, Labelling & Stowage, Temperature Control Technology & Conveyor Design.

Reference Books.

1. High Energy Materials : Propellants, Explosives and Pyrotechnics by Jai Prakash Agrawal
2. Solid Propellant Chemistry by Dr K Kishore and Dr K Sridhara
3. Ballistics : Theory and Design of Guns and Ammunition by Donald E Carlucci and Sidney S Jacobson

Task Books.

1. Ammonium Nitrate Explosives for Civil Applications : Slurries, Emulsions and Ammonium Nitrate Fuel Oils by Erode G Mahadevan
2. Guide to the International Ammunition Technical Guidelines (IATG) by United Nations

Course Objectives.

CO 1 :Fundamentals of Explosives. Understand the classification and properties of explosives (primary, secondary and tertiary).

CO 2 :Design and Formulating of Explosives. Study the process of formulating composite explosives and pyrotechnic mixtures.

CO 3 :Propellants and Energetic Materials. Study ballistics and combustion characteristics of propellants.

CO 4 :Safety, Handling and Storage of Explosives. Understand safety regulations and best practices for handling explosive materials.

CO 5 :Testing and Simulation of Explosives. Study experimental methods for explosive testing and evaluation.

Course Outcomes. After completing this Course, the students will be able to:-

CO 1 :Understand the Fundamentals of Explosives. Explain the chemical composition classification, and properties of various explosive materials.

CO 2 :Apply Knowledge of Explosive Design and Formulation. Design and formulated safe and efficient explosive compositions for different applications.

CO 3 :Analyze the Explosions and Detonations. Predict and evaluate the blast effects and fragmentation patterns of explosives.

CO 4 :Ensure Safe Handling, Storage and Disposal of Explosives. Implement safety protocols and international standards for handling and transporting explosives.

CO 5 :Conduct Testing and Simulation of Explosives. Apply computer-aided simulation tools to model detonation behaviour.

Course Type (PE-II). - Ammunition Technology and Its Integration

Course Code. - TTC 510

1. **Unit I : Armour Material.** Material Sciences, Composite Materials in Armour, Auxetic Materials, Nano Technology in Armour Design, Layering Techniques, Inter Leaved Materials, Kinetic and Chemical Reactive System, Corrosion Resistant Technology, Light Weight Armour, Smart Armour & Protection Against Top Attack.
2. **Unit II : Armour Protection System.** Sensor Technology, Types of Radars, Acoustic Sensors, Contemporary Armour Protection System, Computing modules, Reception Time optimisation, Hard kill Measures and Soft Kill Measures.
3. **Unit III : Stealth Technology.** Radar Absorption Technology, Thermal Signature Radiation, Shape Optimisation, Adaptive Camouflage, Thermoelectric Technology, Modular Camouflage System, Use of Nano Materials & Use of Fabrics.
4. **Unit IV : Reactive Armour.** Non Explosive Reactive Armour, Fragmentation and Blast Mitigation, Weight and Balance Considerations, Smart Reactive Armour & Measures Against Tandem Warheads.

Reference Books.

1. Fundamentals of Guided Missiles by S R Mohan
2. Indian Arms and Armour by G N Pant
3. Securing India : Assessment of the Defence Capabilities by Raja Menon
4. Stealth Technology and Its Effect on Aerial Warfare by VivekKapur
5. Introduction to Explosive Reactive Armour by Harpal Singh Yadav

Text Books.

1. Small Arms & Ammunition by Defence Research and Development Organisation (DRDO)
2. Composite Armour Materials and Modules by T Balakrishna Bhat and VemuriMadhu
3. The Rout ledge Handbook of Indian Defence Policy : Harsh V Pant

Course Objectives.

CO 1 :Fundamentals of Ammunition Technology. Understanding the basic principles of ammunition design and classification.

CO 2 :Ammunition Components and Materials. Exploring different types of propellants, explosives, primers and casings.

CO 3 :Ammunition Design and Manufacturing. Learning about the processes involved in designing and manufacturing various ammunition types.

CO 4 :Ammunition Integration with Weapon Systems. Studying ammunition storage, handling and transportation considerations.

CO 5 :Ammunition Lifecycle Management. Studying stockpile Management, disposal techniques and demilitarization.

CO 6 :Application in Defence and Security. Understanding the impact of emerging technologies on future ammunition systems.

Course Outcomes. After completing this Course, the students will be able to:-

CO 1 :Understand Ammunition Fundamentals. Explain the role of ballistics (internal, external and terminal) in ammunition performance.

CO 2 :Analyze Ammunition Components and Materials. Identify and describe the different components of ammunition, including explosives, propellants, casings and fuzes.

CO 3 :Conduct Testing and Evaluation. Apply testing procedures to assess ammunition performance safety and reliability.

CO 4 :Manage Ammunition Lifecycle and Disposal. Understand environmental regulations and best practices for ammunition disposal and demilitarization.

CO 5 :Assess Ammunition Applications in Defence and Security. Evaluate ethical, legal and environmental considerations in ammunition usage.

Course Type (PE-III). - Weapon System

Course Code - TTC 511

1. **Unit I : Barrel Design.** Material Engineering, Thermal Management, Liner Technology, Ballistic Optimisation, Electromagnetic Guns, Modular Barrel System, Barrel Stabilising System, Smart Barrel Technology (Sensor Fusion), Advanced Materials & Advanced Muzzle Brakes.
2. **Unit II : Gun Cradle Design.** Vibration Dampening System, Modular Cradle Designs, Electronic Firing Mechanics, Automatic Elevation and Traverse System, Heat Management Solutions, Automatic Maintenance Solutions, Composite Cradle for Weight Reduction & Auto Gun Balance Technology.
3. **Unit III : Recoil System Design.** Electro Rheological Fluids (ERF) and Magneto Rheological Fluids (MRF), Monitoring Mechanics, Reducing Impact on Accuracy, Newtonian and Non Newtonian Fluid Incorporation, Hydraulic and Pneumatic System Comparison, Recoil Absorption Technology and Pump Design, Integration with Suspension System & Assessment.
4. **Unit IV : Sighting System.** Electro-Optical Pods, Multi Spectral Sensors, Sighting System Integration, Augmented Reality Displays, Helmet-Mounted Display Technology, Military-intelligence, Adaptive Optics & Compactness in Designs.
5. **Unit V : Target Training & Fire Control System Design.** Kalman filtering and Target Recognition and Localisation, Adaptive Tracking System, Spatial Temporal Processing, Automatic Terrain Adaptation, Target Prioritisation & Target Priority Assignment Algorithms. Advance Sensor Suite, Artificial Intelligence Fusion in Fire Control System, Automatic Ballistic Computation Algorithms, Automated Target Recognition, Human Machine Interface, Network Centric Warfare Capability, Automatic Meteorological Monitoring System, Multi Munition Capability, Simulation and Training Tools.

Reference Books.

1. India's Military Modernization : Strategic Technologies and Weapons Systems by Rajesh Basrur and Bharath Gopalaswamy, Published by Oxford University press in 2015
2. Design of Bridge Structures by TR Jagadeesh and MA Jayaram

3. Theory and Design of Recoil Systems and Gun Carriages by United States Army, Ordnance Dept
4. Optical Engineering : Textbook by M P Grover
5. Control Systems Engineering by IJ Nagrath and M Gopal

Text Books.

1. Advanced Machine Design by V B Bhandari
2. Machine Design by V B Bhandari
3. Design of Machine Elements by R S Khurmi & J K Gupta
4. Optics and Optical Instruments by B K Mathur

Course Objectives.

CO 1 : Understanding Weapon System Fundamentals. Learn the classification of weapon systems (small arms, artillery, Missiles, naval and aerospace weapons)

CO 2 : Ballistics and Firepower. Study ammunition types, propulsion methods and damage mechanisms.

CO 3: Sighting and Guidance Systems. Explore electro-optical and night vision sights.

CO 4 : Weapon Integration and Platforms. Study weapon mounting on land, air, sea and space platforms.

CO 5 : Safety, Reliability & Maintenance. Understand lifecycle management of Military Hardware.

Course Outcomes. After completing this Course, the students will be able to:-

CO 1 : Understand Fundamental Principles of Weapon Systems. Explain the classification, functions and components of different weapon systems.

CO 2 : Operate and Assess Fire Control & Sighting Systems. Understand the working principles of laser, GPS and Artificial intelligences-based targeting systems.

CO 3 :Ensure Safety, Reliability and Maintenance. Implement weapon safety protocols and failure prevention measures.

CO 4 :Research and Innovate in Emerging Weapon Technologies. Explore the future of Unmanned Combat Vehicles (UAVs, UCAVs) and robotic warfare.

CO 5 :Integrate Weapon Systems with Defence Platforms. Assess interoperability in network- centric warfare and modern combat strategies.

Course Name (OJT / FP) - On the Job Training / Internship / Field Project

Course Code- TTC 512

1. **Unit I : Fundamentals of On-the-Job Training.** Understand the core principles of on-the-job training and its role in professional development, Definition and goals of OJT, Benefits for students and organizations and Common OJT methods (eg, shadowing & hands-on practice). Identifying training needs and gaps, setting clear training objectives and outcomes and aligning OJT with organizational goals.

2. **Unit II : Instructional Techniques and Delivery.** Learn effective methods for delivering on-the-job training and engaging trainees. Effective Instructional Techniques, engaging and motivating students, providing feedback and support assessing learning and progress.

3. **Unit III : Advanced Training.** To Explore advanced techniques and strategies for enhancing on-the-job training including customized training approaches, mentoring and coaching, incorporating e-learning and virtual simulations and facilitating learning in diverse environments.

4. **Unit IV : Evaluating and Improving Training Programs.** To Learn how to evaluate the effectiveness of training programs and implement improvements including evaluation methods and tools, carry out continuous improvements, encouraging a culture of continuous learning and development and learning from challenges and case studies.

Course Objectives

CO 1:Enable students to apply theoretical knowledge gained in the classroom to real-world scenarios.

CO 2 :Enhance technical and soft skills relevant to the students' field of study.

CO 3 :Provide students with firsthand experience of industry operations, standards and practices.

CO 4 :Facilitate the building of professional networks and relationships within the industry.

CO 5 :Develop students' problem-solving abilities through real-life challenges and projects.

CO 6 :Assess students' capabilities and performance in a professional setting.

Course Outcomes

CO 1:Demonstrate competence in applying theoretical knowledge to practical tasks in their field.

CO 2 :Exhibit professional behavior, including effective communication, teamwork and adherence to workplace norms.

CO 3 :Develop proficiency in the technical and soft skills required for their chosen profession

CO 4 :Understand and adhere to industry standards and best practices.

CO 5 :Solve problems and make informed decisions in a professional context.

CO 6 :Reflect on their experiences to identify areas for personal and professional growth.

SEMESTER – III

Course Type (PC-VII). - Autonomous Unmanned Ground Vehicles - II

Course Code. - TTC 513

1. **Unit I : Traction Control and Off-Road Manoeuvre.** Advanced Traction Control System for Unmanned Ground Vehicles in Diverse Terrain (Sand, Mud, Snow etc), Artificial Intelligence-Based System for Optimizing Traction Control in off-Road and High-Incline Environments, Role of Adaptive Suspension System in improving Unmanned Ground Vehicle off-Road Manoeuvrability, Advances in Tire and Track Designs for Enhancing Unmanned Ground Vehicle Mobility in Challenging Terrain, Integration of Traction Control with Artificial Intelligence for Predictive Terrain

Recognition and Adaptation, Case Studies of Traction Control System in Unmanned Ground Vehicles for off-Road Military Operations.

2. **Unit II : Advanced Autonomous Steering** Artificial Intelligence -Based Steering Algorithms for Autonomous Unmanned Ground Vehicle Navigation in Complex Terrain, Role of Predictive Control System in Enhancing Unmanned Ground Vehicle manoeuvrability at High Speeds, Integration of Advanced Steering with Obstacle Detection System for improved Navigation, Challenges in Designing Autonomous Steering System for Heavy Military Vehicles, Advances in Sensor-Based Steering Control for Precision Movement in Confined Spaces, Case Studies of Advanced Steering System in Unmanned Ground Vehicles for Urban Warfare and Reconnaissance.

3. **Unit III : Adaptive Camouflage** Technologies for Adaptive Camouflage System in Unmanned Ground Vehicles, Including Thermal and Optical Invisibility, Role of Artificial Intelligence in Real-Time Adaptation of Unmanned Ground Vehicle Camouflage to Changing Environments, Integration of Multispectral Materials for Reducing Unmanned Ground Vehicle visibility across different Spectra, Future Trends in Dynamic Camouflage for Stealth Operation Combat Zones, Case Studies of Adaptive Camouflage in Military Vehicles for reducing Detection, Challenges in Deploying Adaptive Camouflage on Rugged Terrain and in Adverse Conditions.

5. **Unit IV : Unmanned Ground Vehicle with Counter IED.** Role of Unmanned Ground Vehicles in Detecting and Neutralizing IEDS and Landmines in High-Risk Areas, Integration of Ground-Penetrating Radar (GPR) and Sensor Fusion System for Mine Detection, Advances in Robotic Arms and Autonomous System for IED Defuse and Clearance, Artificial Intelligence Algorithms for Recognizing IED Patterns and Improving Detection Accuracy, Future Trends in Fully Autonomous Counter-IED System for Unmanned Ground Vehicles Operations, Case Studies of Unmanned Ground Vehicles Deployed in Counter-IED and Mine Detection Roles in Modern Conflicts.

6. **Unit VI : Mine Detection System & Anti Thermal Paints and Coatings.** Technologies behind Anti Thermal paints and coatings for reducing thermal signature of Unmanned Ground Vehicles, Role of Nanomaterials in Developing Next-Gen Thermal-Resistant Coatings for Military Vehicles, Integration of Anti Thermal Coatings With Adaptive Camouflage for Enhanced Stealth, Challenges in Maintaining Thermal Signature Reduction in Combat and High-Mobility Environments, Future Trends in Anti Thermal Technologies for Unmanned Ground Vehicles Stealth Applications & Case Studies of Anti Thermal Coatings Used in Unmanned Ground Vehicles for Avoiding Detection by Infrared Sensors.

Reference Books

1. Sensors for Chemical and Biological Applications by Manoj Kumar Ram and Venkat R Bhethanabotla
2. A review of Sensing Technologies for Landmine Detection : Unmanned Vehicle-Based Approach by Massey University

Text Books

3. **Autonomous Control Systems and Vehicles** : Intelligent Unmanned Systems "This book delves into the theory and application of robotics and autonomous vehicles, covering topics relevant to both aerial and ground unmanned systems. It provides insights into intelligent control systems that can be applied to hybrid platforms".
4. Thermal Spray Coatings by Lalit Thakur and Hitesh Vasudev

Course Objectives.

CO 1 :Autonomous Navigation and Path Planning. Study obstacle avoidance techniques and real-time motion planning.

CO 2 :Communication and Networking. Learn about cyber security challenges and solutions for autonomous systems.

CO 3:Artificial Intelligence and Machine Learning in Unmanned Ground Vehicles. Understand deep learning and reinforcement learning applications in Unmanned Ground Vehicles autonomy.

Course Outcomes

CO 4 :Applications and Case Studies. Explore military, industrial, agricultural and disaster response applications of Unmanned Ground Vehicles.

CO 5 : Understand Unmanned Ground Vehicles Fundamentals. Explain the principles, history and classifications of autonomous unmanned ground vehicles.

CO 6 : Analyze Unmanned Ground Vehicles Dynamics And Control. Apply kinematic and dynamic modeling of ground vehicle motion.

CO 7 : Apply Artificial Intelligence and Machine Learning in Unmanned Ground Vehicles. Design Artificial Intelligence-decision-making systems for Unmanned Ground Vehicles.

CO 8 : Demonstrate Communication and Networking in Unmanned Ground Vehicles. Understand Cybersecurity measures for secure autonomous operations.

Course Type (PC-VIII) - Combat Power Application: Doctrine

Course Code- TTC 514

1. **Unit I : Infusion of Drone Technology in Various Operations.**

Introduction to Drone Systems, Categorisation, Basic Principles of Flight, System Architecture & Components, Introduction to Video/ Image interpretation & Basics Aerial Imaging, Calibration, Pre Flight and Post Flight Checks, Analysis of Faults and Diagnosis and application in operations of war, Counter Drone Tech including Active and Passive Sys & Measures and simulator practical.

2. **Unit II : Doctrine and Operations.** Organising and employing doctrine of Armoured Fighting Vehicles including Tanks and ICVs, Operations in various terrain, criticalities, challenges, enemy land and air threat, infusion of new technologies and impacts on own capability and operations, Joint operations and challenges including impact of technology& Field exercises.

Reference Books.

1. "Counter-Drone Systems: Technologies and Applications" by Giuseppe Colucci.
2. "Doctrine: The Global War on Terror" by Thomas Donnelly, Frederick W Kagan, and Gary Schmitt.

Task Books.

1. "Drone Warfare: The Development of Unmanned Aerial Conflict" by Dave Sloggett
2. "Joint Operations: Doctrine, Practice and Doctrine" by Ian Beckett and John Pimlott

Course Objectives

CO 1:Familiarisation with Doctrine.

- (a) Gain a comprehensive understanding of military doctrines, including their historical development, theoretical foundations and practical applications.

- (b) Study various doctrines from different military branches and allied forces to understand diverse strategic perspectives.

CO 2 :Understanding Strategic Application.

- (a) Learn to apply military doctrines to real-world scenarios, considering geopolitical, economic and cultural contexts.
- (b) Analyze case studies of past conflicts to identify successful and unsuccessful strategic applications.

CO 3 :Understanding Force Multipliers.

- (a) Identify and evaluate various force multipliers such as technology, intelligence, logistics and alliances.
- (b) Understand how to effectively leverage these multipliers to enhance operational effectiveness and achieve mission objectives.

CO 4 :Planning and Execution of Operations.

- (a) Develop skills in operational planning, including mission analysis, course of action development and risk assessment.
- (b) Practice executing operations through simulations and war gaming, focusing on coordination, communication and decision-making under pressure.

CO 5 :Understanding of Joint Operations.

- (a) Study the principles and practices of joint operations involving multiple branches of the military.
- (b) Learn about interoperability, joint command structures and the integration of land, sea, air and cyber forces in unified missions.

Course Outcomes

CO 1 :Mastery in Strategic Planning.

- (a) Demonstrate proficiency in developing comprehensive strategic plans that align with national defense objectives and adapt to changing conditions.
- (b) Exhibit the ability to anticipate potential challenges and devise contingency plans.

CO 2 :Integration of Force Multipliers in Operations.

- (a) Show capability in identifying and integrating appropriate force multipliers into operational plans to maximize effectiveness and efficiency.
- (b) Evaluate the impact of different multipliers on mission success and adjust strategies accordingly.

CO 3 : Adaptability in Warfare.

- (a) Display a high level of adaptability in response to dynamic and unpredictable operational environments.
- (b) Cultivate the ability to innovate and improvise solutions to emerging threats and challenges.

CO 4 : Command and Leadership.

- (a) Exemplify strong leadership skills, including decision-making, team building and conflict resolution.
- (b) Lead by example, inspiring confidence and trust in subordinates while maintaining a clear focus on mission objectives.

Course Type (PE IV)- Combat Power Application: Operations

Course Code - TTC 515

1. **Unit I : Fundamentals of Land Operations.** Introduction and familiarisation to all operations in various types of terrain, planning, preparation and conduct of operation with impact of latest and contemporary technology.
2. **Unit II : Conduct of Land Operations.** Exercise in various modes to include table top, sand model, computer simulations and field operations.
3. **Unit III : New Generation Warfare.** Introduction and familiarisation of new generation of warfare in global conflicts and disruption of technology & challenges and methods to adopt it.

Reference Books.

1. "Fundamentals of Modern Land Combat" by Clifford J Rogers, John Lynn, and Steven T. Ross
2. "Wargaming for Leaders: Strategic Decision Making from the Battlefield to the Boardroom" by Mark L. Herman and Mark D Frost
3. "Future War: Preparing for the New Global Battlefield" by Robert H Latiff

Text Books.

1. "Military Operations: The Tactics of the Second World War" by JFC Fuller
2. "A Practitioner's Guide to Accelerated Learning and Learning Support in Developing Military Leaders" by Tony Edwards
3. "New Generation Warfare: How to Win in the 21st Century" by Bevin Alexander

Course Objectives.

CO 1: Understand the principles and concepts of combat power application in military operations.

CO 2 : Analyze the factors that influence the effective employment of combat power, including terrain, enemy forces and environmental conditions.

CO 3 : Develop strategies and tactics for the efficient and coordinated use of various combat power elements, such as infantry, armor, artillery and air support.

Course Outcomes.

CO 1: Demonstrate the ability to plan and execute military operations that effectively utilize and integrate different combat power elements to achieve mission objectives.

CO 2 : Apply critical thinking and decision-making skills to adapt combat power application strategies in response to changing operational environments and enemy actions.

CO 3 : Effectively communicate and coordinate combat power application plans and operations with other military units and personnel to ensure unified and synchronized action.

Course Type (PE V & PE VI) - Professional Elective

Course Code- TTC 516 & TTC 517

1. **Unit I :Specialization**. Elective subjects in an MSc program allow students to specialize in a specific area of interest within their field of study, enabling them to gain deeper knowledge and expertise.
2. **Unit II :Flexibility**. Electives provide flexibility in the curriculum, permitting students to tailor their degree to suit their career goals, research interests and personal preferences.
3. **Unit III : Advanced Knowledge**. Elective subjects offer advanced knowledge and skills in a particular domain, enhancing students' understanding and application of concepts in their chosen field.
4. **Unit IV : Research Opportunities**. Electives can serve as a gateway to research opportunities, allowing students to explore topics under the guidance of experienced faculty members, potentially leading to publications or further research.
5. **Unit I : Career Enhancement**. By choosing electives strategically, students can enhance their career prospects, demonstrating to potential employers their specialized skills and knowledge in a specific area, making them more competitive in the job market.

Course Objectives.

CO 1:Gain Specialized Knowledge. Acquire advanced and specialized knowledge in a specific area of study, demonstrating a deeper understanding of the subject matter.

CO 2 :Develop Advanced Analytical Skills. Develop and apply advanced analytical skills to complex problems, demonstrating the ability to think critically and creatively.

CO 3 :Apply Cutting-Edge Techniques and Tools. Learn and apply cutting-edge techniques, tools and methodologies in the field, demonstrating proficiency in using industry-standard software, hardware or equipments.

CO 4 :Foster Innovation and Entrepreneurship. Encourage innovation, entrepreneurship, and creativity in applying knowledge to real-world problems and demonstrating the ability to think outside the box.

CO 5 :Prepare For Advanced Research or Industry Roles. Prepare students for advanced research or industry roles by developing advanced skills in research design, methodology and application, demonstrating the ability to contribute to the field.

SEMESTER – IV

Course Type (Project 1 & Project 2) - Minor Project & Major Project

Course Code- TTC 518 &TTC 519

1. **Unit I – Culminating Experience**. The major project is a culminating experience in an MSc program, requiring students to integrate and apply the knowledge, skills, and expertise acquired throughout their studies.
2. **Unit II – Original Research Contribution**. A major project involves original research, contributing to the existing body of knowledge in the field, and demonstrating students' ability to design, conduct, and report on a comprehensive research study.
3. **Unit III – Advanced Research Skills**. The project helps students develop advanced research skills, including formulating research questions, designing methodologies, collecting and analyzing data, and drawing meaningful conclusions.
4. **Unit IV – Professional Expertise**. The major project demonstrates students' professional expertise and readiness for independent practice or further research, showcasing their ability to work autonomously and make significant contributions to their field.
5. **Unit V – Career And Academic Progression**. A well-executed major project can open doors to career advancement, PhD programs, or further research opportunities, highlighting students' capabilities and potential as researchers, professionals, or academics.

Course Objectives.

CO 1 :Apply Theoretical Concepts to Practical Problems. Demonstrate the ability to apply theoretical knowledge and concepts learned during the MSc program to real-world problems or scenarios.

CO 2 :Develop Research and Analytical Skills. Conduct a systematic investigation, collect and analyze data and draw meaningful conclusions to address a research question or problem.

CO 3 :Design and Implement A Solution. Design, develop and implement a solution to a problem or need, demonstrating technical skills and knowledge in the relevant field.

CO 4 :Evaluate and Communicate Results. Effectively evaluate the outcomes of the project, communicate findings and present results in a clear and concise manner.

CO 5 :Demonstrate Project Management and Teamwork Skills. Plan, execute and manage a project, demonstrating skills in project management, teamwork and collaboration (if applicable).

Course Outcomes.

CO 1:Analyzed a Complex Problem. Students will be able to break down a complex problem into manageable components, identify key issues and develop a clear understanding of the problem domain.

CO 2 :Design and Developed Solution. Students will be able to design, develop and implement a solution to a problem or need demonstrating technical skills and knowledge in the relevant field.

CO 3 :Conducted Independent Research. Students will be able to conduct independent research, collect and analyze data and draw meaningful conclusions to address a research question or problem.

CO 4 :Communicated Technical Information Effectively. Students will be able to effectively communicate technical information, ideas and results in written, oral and visual forms to both technical and non-technical audiences.

CO 5 :Demonstrated Project Management Skills. Students will be able to plan, execute and manage a project, demonstrating skills in project management, time management and self-directed learning.

Course Outcomes.

CO 1:Demonstrated Specialized Knowledge. Students will be able to demonstrate a deep understanding of the subject matter, including current trends, challenges and opportunities.

CO 2 :Applied Advanced Analytical Techniques. Students will be able to apply advanced analytical techniques and tools to complex problems, demonstrating the ability to think critically and creatively.

CO 3 :Design and Develop Innovative Solutions. Students will be able to design and develop innovative solutions to real-world problems, demonstrating the ability to think outside the box and apply knowledge in practical ways.

CO 1:Communicated Complex Ideas Effectively. Students will be able to effectively communicate complex ideas, technical information and research findings to both technical and non-technical audiences.

CO 1:Prepared For Industry Or Research Roles. Students will be prepared for advanced roles in industry or research, demonstrating the ability to apply knowledge, think critically and contribute to the field.

***COMMON COURSES
FOR PG/PHD
PROGRAMMES***

Course Code	Course Name	L – T – P	Credits
DRC 601	Research Methodology	4-0-0	4

Course Objectives:

- The main objective of the Research Methodology course is to introduce the relevant tools of the research process such as research design, research project drafting, research process planning, and scientific writing, to prepare for writing PhD students' doctoral thesis and for writing research papers in their scientific area.
- The comprehensive course focuses on the relevant topics of research methodology and offers the opportunity to improve student research projects in various areas of their research. This course should strengthen and complement the skills of research methodology that students have already acquired at their home universities.
- The activity of preparing common research project papers following the research methodology course strengthens the knowledge acquired in the course and develops the practical skills to solve real-world problems. The students work in international, inter-institutional, and interdisciplinary teams on joint research projects on innovative topics under the supervision of the faculty of the programme and partner country universities.
- To give an overview of the research methodology and explain the techniques of defining a research problem.
- To explain carrying out a literature search, its review, developing theoretical and conceptual frameworks, and writing a review in research
- To explain various research designs and their characteristics.
- To explain the details of sampling designs, measurement and scaling techniques, and different methods of data collection, several parametric tests of hypotheses, and the Chi-square test.
- To explain the art of interpretation and the art of writing research reports.
- To explain various forms of intellectual property, its relevance, and business impact in the changing global business environment.
- To discuss leading National /International Instruments concerning Intellectual Property Rights.

Course Contents

Unit I: Research Methodology: Introduction, Meaning of Research, Objectives of Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Research Process, Criteria of Good Research, Problems Encountered by Researches to India. Defining the Research Problem: Research Problem, Selecting the Problem, Necessity of Defining the Problem. Technique Involved in Defining a Problem, An Illustration.

Unit II: Reviewing the Literature: Place of the literature review in research, Bringing clarity and focus to the research problem, improving research methodology, Broadening the knowledge base in the research area, enabling contextual findings, Review of the literature, Searching the existing literature, Reviewing the selected literature, Developing a theoretical framework, Developing a conceptual framework, Writing about the literature reviewed Research Design: Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Important Experimental

Designs.

Unit III: Research Ethics, IPR, and Scholarly Publishing: Ethics-ethical issues, ethical committees (human & animal); IPR–intellectual property rights and patent law, Commercialization, Copyright, Royalty, Trade-related aspects of intellectual property rights (TRIPS); The concept, Intellectual Property System in India. Development of TRIPS Complied Regime in India, Patents Act 1970, Trade Mark Act 1999, The Designs Act 2000, Protection of Intellectual Property under TRIP, Copyright and Related Rights, Industrial Designs, Patents, Patentable Subject Matter, Rights Conferred, Exceptions, Terms of Protection, Conditions on Patent Applicants, Process Patents, Scholarly publishing – Concept and design of research paper, Citation and acknowledgment, Plagiarism, Reproducibility and Accountability.

Unit IV: Interpretation, Reporting, and Thesis Writing: Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Structure, and components of scientific reports, types of reports: technical reports and thesis, Thesis writing – different steps and software tools (Word processing, etc) in the design and preparation of the thesis, layout, structure (chapter plan) and language of typical reports, Illustrations, and tables, bibliography, referencing and footnotes, Oral presentation – planning, software tools, creating and making effective presentation, use of visual aids, the importance of effective communication.

Unit V: Computer Lab/Computer Application in Research: The following are to be practiced in Computer Lab: Spreadsheet application, features and functions, using formulas and functions, data storing, Document and Presentation tool: features and functions, Using Latex, Open-office and MS Office creating presentations, master page, adding animation, customizing animation, creating handouts. Web search: introduction to the internet using a search engine, relevance to search terminology, Advanced search.

Unit VI: Data Analysis, Research and Inferential Statistics: Mathematical Modelling, Testing of Hypotheses-Hypothesis, Basic Concepts Concerning Testing of Hypotheses, Test Statistics and Critical Region, Critical Value and Decision Rule, Procedure of Hypothesis Testing, Hypothesis Testing for Mean, Proportion Variance for Difference of Two Mean- Two Proportions-Two Variances, P-Value approach, Power of Test, Limitations of the Tests of Hypothesis, The z-test, The Sampling Distribution. The Standard Error of the Mean Calculation and Interpreting the One-Tailed z Test, Two-tailed z-test, the t-test, student's t distribution, Calculation and Interpreting the One-Tailed t-test, Two-tailed t-test, Chi-squared (χ^2) Test - Test of Difference of more than Two Proportions, Test of Goodness of Fit, Caution, and Interpreting the Chi-Square.

Text & Reference Books

1. Research Methodology: An Introduction by C. R. Kothari, New Age International Publishers
2. Research Methodology: Methods and Techniques by C. R. Kothari, New Age International Publishers
3. Research Methodology for Business: A Skill-based Approach by Kumar, Shekaran (2009), New York, John Wiley Publishers
4. Research Methodology – A Step-by-Step Guide for Beginners, Kumar, Ranjit, (2nd ed), Pearson Education, Sinha P. K., Computer Fundamental, BPB Publishing
5. Computer Application in Phys, S. Chandra: Narosa Pub. House
6. Design and Analysis of Experiments, D. C. Montgomery, Wiley
7. Applied Statistics & Probability for Engineers, D. C. Montgomery & G. C. Runger, Wiley
8. Research Methods and Statistics: A Critical Thinking Approach, Sherri L Jackson, 3rd Edition 2009, 2006 Wadsworth, Cengage Learning

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| <ol style="list-style-type: none">9. Study Material (For the topic Intellectual Property under module 3)Professional Programme Intellectual Property Rights, Law and Practice, Institute of Company Secretaries of Indi, Statutory Body Under the Act of Parliament, September 201310. How to Read an Engineering Research Paper by William Griswold. UC at San Diago11. How to Write an Effective Literature Review by Sonia Martinez, University of California12. How to write a research journal article in Engineering and science by Scott A. Socolofsky |
| |

Course Code	Course Name	L – T – P	Credits
PGC 601	Research Methodology and IPR	2-0-0	2
Course Objectives: • The main objective of this course is to introduce the basic concepts in research methodology. • This course addresses the issues inherent in selecting a research problem and discusses the techniques and tools to be employed in completing a research project. • This will also enable the students to prepare report writing and research article writing.			
Course Contents Unit I: Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations Unit II: Effective literature studies approaches, analysis Plagiarism, Research ethics Unit III: Effective technical writing, how to write a report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee Unit IV: Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, and development. International Scenario: International Cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT. Unit V: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications Unit VI: New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software, etc. Traditional knowledge Case Studies, IPR, and IITs.			
Course Outcomes			
After completing this course, the students will be able to: CO1: Understanding the fundamentals of research and its methodology CO2: Choose the appropriate research design and develop the appropriate research hypothesis for a research project CO3: Knowledge of manuscript preparation, patents, and Intellectual property CO4: Technology transfer and application of IPR in various domains.			

Text Books
19. Research methodology: an introduction for science & engineering students, Stuart Melville and Wayne Goddard. 20. Research Methodology: An Introduction, Wayne Goddard and Stuart Melville. 21. Research Methodology: A Step-by-Step Guide for beginners, 2nd Ed., Ranjit Kumar. 22. Resisting Intellectual Property, 2007, Halbert, Taylor & Francis Ltd. 23. Industrial Design, 1992, Mayall, McGraw Hill. 24. Product Design, 1974, Niebel, McGraw Hill.
Reference Books
1. Introduction to Design, 1962, Asimov, Prentice Hall. 2. Intellectual Property in New Technological Age, 2016, Robert P. Merges, Peter S. Menell, Mark A. Lemley. 3. Intellectual Property Rights Under WTO, 2008, T. Ramappa, S. Chand.

Course Code	Course Name	L – T – P	Credits
PGC 602	Communication Skills & Personality Development	2-0-0	2
Course Contents a) English for Research Paper Writing b) Disaster Management c) Sanskrit for Technical Knowledge d) Value Education e) Constitution of India f) Pedagogy Studies g) Stress Management by Yoga h) Personality Development through Life Enlightenment Skills			

Course Code	Course Name	L – T – P	Credits
RM 501	Research Methodology	3-0-2	4

Course Objectives:

- The main objective of the Research Methodology course is to introduce the relevant tools of the research process such as research design, research project drafting, research process planning, and scientific writing, to prepare for writing PhD students' doctoral thesis and for writing research papers in their scientific area.
- The comprehensive course focuses on the relevant topics of research methodology and offers the opportunity to improve student research projects in various areas of their research. This course should strengthen and complement the skills of research methodology that students have already acquired at their home universities.
- The activity of preparing common research project papers following the research methodology course strengthens the knowledge acquired in the course and develops the practical skills to solve real-world problems. The students work in international, inter-institutional, and interdisciplinary teams on joint research projects on innovative topics under the supervision of the faculty of the programme and partner country universities.
- To give an overview of the research methodology and explain the techniques of defining a research problem.
- To explain carrying out a literature search, its review, developing theoretical and conceptual frameworks, and writing a review in research
- To explain various research designs and their characteristics.
- To explain the details of sampling designs, measurement and scaling techniques, and different methods of data collection, several parametric tests of hypotheses, and the Chi-square test.
- To explain the art of interpretation and the art of writing research reports.
- To explain various forms of intellectual property, its relevance, and business impact in the changing global business environment.
- To discuss leading National /International Instruments concerning Intellectual Property Rights.

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Unit II: Reviewing the Literature: Place of the literature review in research, Bringing clarity and focus to the research problem, improving research methodology, Broadening the knowledge base in the research area, enabling contextual findings, Review of the literature, Searching the existing literature, Reviewing the selected literature, Developing a theoretical framework, Developing a conceptual framework, Writing about the literature reviewed Research Design: Meaning of Research Design, Need for Research Design, Features of a Good Design, Important Concepts relating to Research Design, Different Research Designs, Basic Principles of Experimental Designs, Important Experimental

Designs.

Unit III: Research Ethics, IPR, and Scholarly Publishing: Ethics-ethical issues, ethical committees (human & animal); IPR–intellectual property rights and patent law, Commercialization, Copyright, Royalty, Trade-related aspects of intellectual property rights (TRIPS); The concept, Intellectual Property System in India. Development of TRIPS Complied Regime in India, Patents Act 1970, Trade Mark Act 1999, The Designs Act 2000, Protection of Intellectual Property under TRIP, Copyright and Related Rights, Industrial Designs, Patents, Patentable Subject Matter, Rights Conferred, Exceptions, Terms of Protection, Conditions on Patent Applicants, Process Patents, Scholarly publishing – Concept and design of research paper, Citation and acknowledgment, Plagiarism, Reproducibility and Accountability.

Unit IV: Interpretation, Reporting, and Thesis Writing: Meaning of Interpretation, Technique of Interpretation, Precaution in Interpretation, Structure, and components of scientific reports, types of reports: technical reports and thesis, Thesis writing – different steps and software tools (Word processing, etc) in the design and preparation of the thesis, layout, structure (chapter plan) and language of typical reports, Illustrations, and tables, bibliography, referencing and footnotes, Oral presentation – planning, software tools, creating and making effective presentation, use of visual aids, the importance of effective communication.

Unit V: Computer Lab/Computer Application in Research: The following are to be practiced in Computer Lab: Spreadsheet application, features and functions, using formulas and functions, data storing, Document and Presentation tool: features and functions, Using Latex, Open-office and MS Office creating presentations, master page, adding animation, customizing animation, creating handouts. Web search: introduction to the internet using a search engine, relevance to search terminology, Advanced search.

Unit VI: Data Analysis, Research and Inferential Statistics: Mathematical Modelling, Testing of Hypotheses-Hypothesis, Basic Concepts Concerning Testing of Hypotheses, Test Statistics and Critical Region, Critical Value and Decision Rule, Procedure of Hypothesis Testing, Hypothesis Testing for Mean, Proportion Variance for Difference of Two Mean- Two Proportions-Two Variances, P-Value approach, Power of Test, Limitations of the Tests of Hypothesis, The z-test, The Sampling Distribution. The Standard Error of the Mean Calculation and Interpreting the One-Tailed z Test, Two-tailed z-test, the t-test, student's t distribution, Calculation and Interpreting the One-Tailed t-test, Two-tailed t-test, Chi-squared (χ^2) Test - Test of Difference of more than Two Proportions, Test of Goodness of Fit, Caution, and Interpreting the Chi-Square.

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15. Research Methodology for Business: A Skill-based Approach by Kumar, Shekaran (2009), New York, John Wiley Publishers
16. Research Methodology – A Step-by-Step Guide for Beginners, Kumar, Ranjit, (2nd ed), Pearson Education, Sinha P. K., Computer Fundamental, BPB Publishing
17. Computer Application in Phys, S. Chandra: Narosa Pub. House
18. Design and Analysis of Experiments, D. C. Montgomery, Wiley
19. Applied Statistics & Probability for Engineers, D. C. Montgomery & G. C. Runger, Wiley
20. Research Methods and Statistics: A Critical Thinking Approach, Sherri L Jackson, 3rd Edition 2009, 2006 Wadsworth, Cengage Learning

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| <ol style="list-style-type: none">21. Study Material (For the topic Intellectual Property under module 3)Professional Programme Intellectual Property Rights, Law and Practice, Institute of Company Secretaries of Indi, Statutory Body Under the Act of Parliament, September 201322. How to Read an Engineering Research Paper by William Griswold. UC at San Diago23. How to Write an Effective Literature Review by Sonia Martinez, University of California24. How to write a research journal article in Engineering and science by Scott A. Socolofsky |
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