COURSES OF STUDY
FOR
POSTGRADUATE PROGRAMMES

(2024 – 2026)

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

CONTENTS

1. M.Tech Programmes for the Academic Batch 2024-26

2. MASTER OF SCIENCE (M.Sc.) PROGRAMMES

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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 2024-2025

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	15th July – 26th July 2024	06th Jan - 17th Jan 2025
2	PhD Progress review by DRMC	15th July – 31st July 2024	09th Jan – 31st Jan 2025
3	Last Date of Late Registration with late fee	30th Aug 2024	31st Jan 2025
4	Sending Certified list of courses (Regular Self stud audit etc) registered by the students by Jt Reg. (AC) to COE	30th Sep 2024	28th Feb 2025
5	Commencement of Classes including Preparation	15th July – 22nd Nov 2024 (19 weeks)	13th Jan 2025 – 23rd May 2025 (19 weeks)
6	Project work (for 2nd year)	08th July – 15th Nov 2024 (19 weeks)	16th Dec 2024 – 25th Apr 2025 (19 weeks) for the 4th semester
7	Sport/Cultural/NSS/Other student-related activities	----	15th Feb – 23rd Feb 2025 (1 week)
8	Sending the Panel of Examiners to CoE	06th Sep 2024	17th March 2025
9	Last date of submission of Examination form and Admit Card to COE by respective Departments/Schools	30th Sep 2024	18th Apr 2025
10	Oral Examination Committee approved by Vice Chancellor to be sent to COE – Phase I Thesis evaluation/ Phase II Final Thesis Evaluation	13th Nov 2024	23rd Apr 2025
11	Phase I Thesis evaluation/ Phase II Final Thesis evaluation (MTech/MSc)	18th Nov – 29th Nov 2024	28th Apr – 07th May 2025
12	End Semester Examination	25th Nov – 13th Dec 2024	26th May – 11th June 2025
13	Skill Development Programme/Workshops/IIC Activities as per NEP 2020	14th Dec 2024 – 23rd Dec 2024	-----
14	Last date for submission of certified statement of Marks to COE (Courses/Seminar/Lab/Thesis)	17th Dec 2024	13th June 2025
15	Result Declaration – Autumn Semester	24th Dec 2024	14th July 2025
16	Winter/Summer Vacation for Faculty	26th Dec 2024 - 08th Jan 2025 (2 weeks)	16th June – 13th July 2025 (4 weeks)
17	Outstation Instructional Tour (Optional)	During the period provided for classes without affecting any academic activities	

Programmes Structure
&
Syllabus of Courses

Department of Aerospace Engineering

DEPARTMENT OF AEROSPACE ENGINEERING

The Department of Aerospace Engineering, formerly known as Faculty of Guided Missiles was established with a mission to impart knowledge to scientists and service officers to take up the challenges in design, development and use of Guided Missiles. Later scope was widened to aerospace vehicles including UAVs.

Vision of the Department: To be a centre of excellence for education, training and research in Aerospace Technologies.

Mission of the Department: To impart higher education and pursue research in the field of Aerospace Engineering and Technology having a bearing on the defence requirements for the officers of the Ministry of Defence, Armed Forces, Public Sector Undertakings, other related organizations and general public.

Research Areas:

- Shock wave and boundary layer interaction
- Grid fins
- UAV/ Aircraft Design
- Flight Guidance & Control
- Aero-Thermodynamics
- Flow Control
- Corrugated Airfoils for MAVs
- Aeroelasticity
- Aerospikes
- UAV Swarms
- Aircraft System Identification and Parameter Estimation
- Linear and Nonlinear Control of Aircrafts
- Path planning of UAVs
- Engine Health Monitoring, IVHM
- AI/ML for Aerospace Engineering

M. Tech. in Aerospace Engineering (Guided Missiles) 2024-2026 Batch

Brief Description: The department has been involved in conducting post-graduate program in Aerospace Engineering with specialization in Guided Missiles Technology. This program consists of courses in areas of aerospace engineering with relevance to guided missiles. Curriculum of the program was formulated to meet the needs of Tri-services, Defence R&D Organization, and Public Sector Undertakings dealing with missiles and related technologies. From academic year 2009-10 onwards, the program was also opened up for civilian GATE qualified students.

Eligibility: B.E./B. Tech. degree in Aerospace, Aeronautical or AeSI / Mechanical/ Electrical/ Electronics/ Electronics and Communication / from recognized university.

Organization: The program will be of four-semester duration. In the first semester there are seven courses. In the second semester there are seven courses out of which four courses are electives. The third and fourth semesters are completely devoted for dissertation. All courses will have three tests and a final examination. Half yearly evaluation of the dissertation takes place at the end of the third semester. At the end of the final semester the student submits his/her thesis and makes a presentation which is evaluated by a committee consisting of Internal and External examiners. Visits to various DRDO labs, National Laboratories, etc are planned to enhance student‘s appreciation & understanding of the subject.

M. Tech. in Aerospace Engineering (Guided Missiles) 2024 – 2026 Batch

Semester I

Sl. No.	Course Code	Course	Credits L	Credits T/P	Total Credits (*)
1	AM 607	Mathematics for Engineers	3	1	4
2	AE 601	Aerospace Propulsion	3	1	4
3	AE 602	Aerodynamics	3	1	4
4	AE 603	Navigation, Guidance & Control	3	1	4
5	AE 605	Flight Mechanics	3	1	4
6	AE 606	Flight Instrumentation	3	1	4
7	PGC 601	Research Methodology & IPR	2	0	2
		Total	**20**	**6**	**26**

Semester II

Sl. No.	Course Code	Course	Credits L	Credits T/P	Total Credits (*)
1	AE 604	Aerospace Structures	3	1	4
2	AE 607	Missile Propulsion	3	1	4
3		Elective – I [From Department]	3	1	4
4		Elective – II [From Department]	3	1	4
5		Elective – III	3	1	4
6		Elective – IV	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	**20**	**6**	**26**

Note: 04 weeks Practice school during summer vacation for scholarship students.

Semester III

Sl. No.	Course Code	Course	Credits L	Credits T/P	Total Credits (*)
3	AE 651	M. Tech. Dissertation Phase I	28**		14
		Total	**28**		**14**

Semester IV

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	AE 652	M.Tech. Dissertation Phase II	28**		14
		Total	**28**		**14**

****Contact Hours/week**

List of Electives

Sl. No.	Course Code	Course
1	AE 608	UAV Design
2	AE 609	Guidance & Control for Aerospace Vehicles
3	AE 610	Missile Guidance & Control
4	AE 611	UAV Guidance & Control
5	AE 612	Experimental Aerodynamics
6	AE 613	Computational Aerodynamics
7	AE 614	Structural Dynamics and Aero-elasticity
8	AE 615	Estimation and Tracking for Aerospace Applications
9	AE 616	Nonlinear and Robust Control
10	AE 617	Avionics
11	AE 618	Robotic Control
12	AE 619	Signals and Systems
13	AE 620	Optimal Control with Aerospace Applications
14	AE 621	Advanced Missile Guidance
15	AE 622	Ducted Rocket & Combustion
16	AE 623	Experimental Methods in Fluid Mechanics
17	AE 624	Aircraft Assembly, Inspection & Tests
18	AE 625	Hypersonic Flow
19	AE 626	Compressible Fluid Flow
20	AE 627	Flow Stability and Turbulence
21	AE 628	Missile Aerodynamics
22		Open electives from other Departments

M. Tech. in Aerospace Engineering (UAVs)
2024-2026 Batch

Brief Description: This program was commenced in 2016 and consists of courses in areas of aerospace engineering with relevance to UAVs. The curriculum of the program was formulated to meet the needs of the tri-services, Defence R&D Organization, and Public Sector undertakings dealing with UAVs and related technologies.

Eligibility: B.E./B. Tech. degree in Aerospace, Aeronautical or AeSI / Mechanical/ Electrical/ Electronics/ Electronics and Communication / from recognized university.

Organization: The program will be of four-semester duration. In the first semester there are seven courses. In the second semester there are seven courses out of which four courses are electives. The third and fourth semesters are completely devoted for dissertation. All courses will have three tests and a final examination. Half yearly evaluation of the dissertation takes place at the end of the third semester. At the end of the final semester the student submits his/her thesis and makes a presentation which is evaluated by a committee consisting of Internal and External examiners. Visits to various DRDO labs, National Laboratories, etc. are planned to enhance student‘s appreciation & understanding of the subject.

M. Tech. in Aerospace Engineering (UAVs)
2024 – 2026 Batch

Semester I

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	AM 607	Mathematics for Engineers	3	1	4
2	AE 601	Aerospace Propulsion	3	1	4
3	AE 602	Aerodynamics	3	1	4
4	AE 603	Navigation, Guidance & Control	3	1	4
5	AE 605	Flight Mechanics	3	1	4
6	AE 606	Flight Instrumentation	3	1	4
7	PGC 601	Research Methodology & IPR	2	0	2
		Total	**20**	**6**	**26**

Semester II

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	AE 604	Aerospace Structures	3	1	4
2	AE 608	UAV Design	3	1	4
3		Elective – I [From Department]	3	1	4
4		Elective – II [From Department]	3	1	4
5		Elective – III	3	1	4
6		Elective – IV	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	**20**	**6**	**26**

Note: 04 weeks Practice school during summer vacation for scholarship students

Semester III

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
3	AE 651	M. Tech. Dissertation Phase I	28**		14
		Total	**28**		**14**

Semester IV

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	AE 652	M.Tech. Dissertation Phase II	28**		14
		Total	**28**		**14**

****Contact Hours/week**

List of Electives

Sl. No.	Course Code	Course
1	AE 607	Missile Propulsion
2	AE 609	Guidance & Control for Aerospace Vehicles
3	AE 610	Missile Guidance & Control
4	AE 611	UAV Guidance & Control
5	AE 612	Experimental Aerodynamics
6	AE 613	Computational Aerodynamics
7	AE 614	Structural Dynamics and Aero-elasticity
8	AE 615	Estimation and Tracking for Aerospace Applications
9	AE 616	Nonlinear and Robust Control
10	AE 617	Avionics
11	AE 618	Robotic Control
12	AE 619	Signals and Systems
13	AE 620	Optimal Control with Aerospace Applications
14	AE 621	Advanced Missile Guidance
15	AE 622	Ducted Rocket & Combustion
16	AE 623	Experimental Methods in Fluid Mechanics
17	AE 624	Aircraft Assembly, Inspection & Tests
18	AE 625	Hypersonic Flow
19	AE 626	Compressible Fluid Flow
20	AE 627	Flow Stability and Turbulence
21	AE 628	Missile Aerodynamics
22		Open electives from other Departments

Course Code	Course Name	L – T – P	**Credits**
AE 601	**Aerospace Propulsion**	3-1-0	**4**

Course Objectives:

- To impart knowledge about various Aerospace Propulsion Systems.
- To introduce the fundamental of Aerothermodynamics.
- To enable the students to understand the design and operation of Aerospace Propulsion Systems.

Course Contents

Unit I

Introduction: Classification & mode of operation of various Propulsion Systems.

Unit II

Basic Thermodynamics & Fluid Dynamics: Thermodynamic Laws, Conservation laws for mass, momentum and energy, Thrust Equation, Compressible flow, Isentropic Relations, Normal & Oblique Shock Waves, Quasi One-Dimensional flow through variable area ducts, Flow with Friction and Heat Transfer.

Unit III

Gas Turbine Engine: Parametric Analysis of Ideal Turbojet, Turbofan & Turboprop engine, Specific Fuel Consumption, Propulsive, Thermal & Overall Efficiency, Component Performance (Subsonic & Supersonic Inlets, Axial and Centrifugal Compressors, Combustor, Turbine & Nozzle)

Unit IV

Piston Engines: Cycle Analysis, Engine Components and Classification, Engine Systems (Fuel Injection, Ignition, Lubrication, Supercharging, Inter Cooling)

Unit V

Propellers: Classical Momentum Theory, Blade Element Theory, Variable Speed Propeller, Propeller Charts, Performance Selection & Matching, Ducted Propellers.

Unit VI

UAV Propulsion: Electric Motors, Solar Cells, Advanced Batteries, Fuel Cells, Future Technology.

Course Outcomes

After completing this course, the students will be able to:
CO1: Learn about Aerothermodynamics
CO2: Learn design and operation or various propulsion systems
CO3: Solve problems on Gas Dynamics
CO4: Design and learn about Aircraft Propellors
CO5: Learn about electric propulsion systems like electric motors, batteries and future technologies

Text Books
1. Saeed Farokhi, ―Aircraft Propulsion‖ 2nd Edition, Wiley 2. Jack L. Kerrebrock, ―Aircraft Engines & Gas Turbines‖ 2nd Edition, MIT Press 3. J. Mattingly & H. von Ohain, ―Elements of Propulsion: Gas Turbines & Rockets‖ AIAA Education, 4. Philip Hill & Carl Peterson, ―Mechanics and Thermodynamics of Propulsion‖ 2nd Edition, Prentice Hll
Reference Books
1. Gordon C Oates, ―Aerothermodynamics of Gas Turbine and Rocket Propulsion‖ 3rd Edition, AIAA Education, 2. Maurice J Zucrow, ―Aircraft and Missile Propulsion‖, Vol 1 & 2, Wiley

Course Code	**Course Name**	**L – T – P**	**Credits**
AE 602	**Aerodynamics**	**3-1-0**	**4**

Course Objectives:

- To understand the governing equations of fluid flow, concept of vorticity, stream function and potential function.
- To familiarize the potential flow problems like circular cylinder with and without free vortex.
- To understand flow over airfoils and wings. Also, to solve practical problems on aerodynamic characteristic of airfoils, wings and aerospace vehicle.
- To understand different shock waves (normal, oblique and expansion waves) and to solve problems.
- To familiarize with wind tunnel experiments & basic introduction to Experimental Aerodynamics

Course Contents

Unit I

Incompressible flow: Introduction, Governing equations, Flow kinematics, Elementary flows, Non-lifting and lifting flows, Flow over airfoils; Kutta-Joukowski theorem, Kutta conditon, Kelvin‘s theorem, Thin airfoil theory; Flow over wings; Prandtl‘s lifting line theory; Viscous fluid flow, Turbulent flow, flow separation, Boundary layer.

Unit II

Fluid Dynamics (Compressible flow): 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 III

Aerodynamic characteristics of aerospace vehicles: Aerodynamic characteristics of Missiles, low Reynolds number aerodynamics (UAVs / MAVs).

Unit IV

Experimental Aerodynamics: Introduction to experimental aerodynamics, & types of wind tunnels, instruments, wind tunnel experiments.

Course Outcomes
After completing this course, the students will be able to: **CO1:** To derive the governing equations of fluid flow. Understand the concept of vorticity, stream function, and potential function. Formulate the potential flow problems over circular cylinder. **CO2:** To derive airfoils and wing theories. Solve various practical problems on aerodynamic characteristics of airfoils and wings. **CO3:** To derive shock relations and solve various normal shock, oblique shock and expansion waves problems encountered in aerodynamics. Understand the basics of hypersonic flow. **CO4:** To solve problems on aerodynamic characteristics of Aerospace Vehicle. **CO5:** To Conduct experiments: 1. On flow visualization 2. On aerodynamic characteristics of aerospace vehicles.
Text Books
1. John D. Anderson, Fundamentals of Aerodynamics, 4th Edition, McGraw Hill, 2006. 2. E. L. Houghton and P. W. Carpenter, Aerodynamics for Engineering Students, 5th Edition, Butterworth-Heineman, Oxford, 2003. 3. John D. Anderson, Introduction to flight, 5th Edition, McGraw Hill, 2005
Reference Books
1. F. M. White, Viscous Fluid Flow, McGraw Hill, 2006. 2. F. M. White, Fluid Mechanics, McGraw Hill, 2003. 3. Fox and MacDonald, Introduction to Fluid Mechanics, 5th Edition, John Wiley & Sons, inc, 2003. 4. John D. Anderson, Modern Compressible Flow: With Historical Perspective, 3rd Ed, 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. S. S. Chin, Missile Configuration Design, McGraw Hill, 1961. 8. Michael R. Mendenhall, Tactical Missile Aerodynamics,2nd Ed., AIAA Publications, 1992. 9. Reg Austin, Unmanned aircraft Systems: Uavs design, development and deployment, John Wiley & Sons, inc, 2010

Course Code	Course Name	L – T – P	Credits
AE 603	**Navigation, Guidance and Control**	**3-1-0**	**4**
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.			
Course Contents **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, Millimeteric 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.

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 analyse a control system to meet the specific requirements.

Text Books

1. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, New Delhi, 2001.
2. Myron Kayton & Walter R. Fried, Avionics Navigation Systems, John Wiley & Sons, 1997.
3. P. Zarchan, Tactical & Strategic Missile Guidance, American Institute of Aeronautics and Astronautics, 2007
4. G. M. Siouris, Missile Guidance and Control Systems, Springer, 2004
5. K. Ogata, Modern Control Engineering, Prentice Hall of India, 1995.

Reference Books

1. John H. Blakelock, Automatic Control of Aircraft and Missiles, Wiley, 1991
2. Anthony Lawrence, Modern Inertial Technology, Springer, 1998
3. Ching Fang Lin, Modern Navigation, Guidance and Control Processing, Prentice Hall, 1991
4. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.
5. Albert Helfrick, Principles of Avionics, Avionics Communications, 2009

Course Code	Course Name	L – T – P	**Credits**
AE 604	**Aerospace Structures**	3-1-0	**4**

Course Objectives:

- To impart knowledge about Aerospace Structures.
- To introduce the fundamental of Aerospace Materials.
- To enable the students to understand the design of Aerospace Structures.
- To enable students to analyze Aerospace Structures

Course Contents

Unit I

Review of Strength of Materials.

Unit II

Introduction to Aerospace Materials: Metal Alloys and Fiber Reinforced Composite.

Unit III

Introduction to different types of constructions: Monocoque, Semi-Monocoque, Truss, and Corrugated shell.

Unit IV

Introduction to Aircraft and Missile Structural Components: Spars; Ribs; Stringer; Longerons.

Unit V

Analysis of stress & strain: Material Constitutive Relations; Analysis of pressure vessels; Bending, Shear and torsion of thin-walled members; Buckling of Columns; Failure Theories

Unit VI

Introduction to Vibration and Fatigue.

Course Outcomes

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

CO1: Learn about Aerospace Structures

CO2: Learn design and construction of various structural components

CO3: Solve problems in Structural Design

CO4: Learn about Vibration and Fatigue

Text Books

1. David J. Peery, Aircraft Structures, Dover Publications, 2011
2. E. F. Bruhn, Analysis and Design of Flight Vehicle Structures, S.R. Jacobs, 1973

Reference Books

1. T. H. G. Megson, Aircraft Structures for Engineering Students, Butterworth-Heinemann, 2010.
2. G. F. Titterton, Aircraft Materials and Processes, Himalayan Books, 2013.

Course Code	**Course Name**	**L – T – P**	**Credits**
AE 605	**Flight Mechanics**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about the flight performance & its concepts
- To enable the students to understand flight stability & control

Course Contents

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.

Course Outcomes

After completing this course, the students will be able to:
CO1: Learn about the basic concepts of flight performance.
CO2: To gain knowledge about the flight stability & its applications

Text Books

1. B. 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.
4. John D Anderson, JR, Introduction to Flight, Tata McGraw-Hill, New Delhi.

Reference Books

1. Michael R. Mendenhall, Tactical Missile Aerodynamics, 2nd Ed., AIAA Publications, 1992.
2. Eugene L. Fleeman, Missile Design and System Engineering, AIAA Education Series, 2012.
3. J.J. Jerger, System Preliminary Design, D. Van Nostrand Co., Inc., Princeton, New Jersey, 1960.
4. A.E. Puckett and Simon Ramo, Guided Missile Engineering, McGraw Hill, 1989.

Course Code	Course Name	L – T – P	Credits
AE 606	**Flight Instrumentation**	**3-1-0**	**4**

Course Objectives:

- To understand the basic concepts of measurements.
- To impart knowledge about the Signal processing.
- To introduce the fundamental concepts of Data transmission
- To enable the students to understand various types of tracking & data fusion

Course Contents

Unit I

Basic concepts of measurements: Generalized characteristics of sensors, instruments, and measurement systems. Measurement of physical quantities such as pressure, force, altitude, temperature, flow, strain and vibration, and angle of attack. Inertial sensors: gyroscope and accelerometer with recent advancements therein.

Unit II

Signal processing: Operational amplifiers, instrumentation and Charge amplifiers. Analog to digital and digital to analog converters. Data acquisition system.

Unit III

Data transmission: Signal transmission by analog and digital means, methods of modulation and demodulation, multiplexing time division and frequency division, telemetry systems and trajectory tracking devices such as Electro-optic tracking systems.

Unit IV

Tracking and data fusion: Thermal imagining system, scanning techniques, detectors and range analysis and multi sensor data fusion for trajectory analysis.

Course Outcomes

After completing this course, the students will be able to:
CO1: Learn the basics of various concepts of measurements
CO2: Learn about the processes of signal processing devices and its applications
CO3: Learn about the concept of data transmission & telemetry systems
CO4: To gain knowledge about data tracking & fusion techniques and its applications

Text Books

1. J.M. Lloyd, Thermal imaging system, Plenum Pub., New York, 1975
2. D. Patranabis, Telemetry Principles, Tata McGraw Hill, New York, 2000.

Reference Books

1. E.O. Doebelin, Measurement Systems: Application and Design, 4thEd, McGraw Hill International, New York, 1990

Course Code	Course Name	L – T – P	**Credits**
AE 607	**Missile Propulsion**	3-1-0	**4**

Course Contents

Unit I

Introduction: Classification and characteristics of various propulsive devices used for Missiles & Weapon Systems.

Unit II

Thermodynamic Cycle Analysis: Engine cycles (Turbojet, Turbofan, Pulsejet, Ramjet and Rocket Engine). Thrust equation, specific impulse & fuel consumption. Thermal efficiency, propulsive efficiency & overall efficiency of propulsion systems.

Gas Dynamics: Equation of state, internal energy, enthalpy & entropy of an ideal gas. Laws of conservation of mass, momentum, and energy. Wave equation and velocity of sound. Quasi one dimensional gas flows. Characteristic parameters. Methods of solving one-dimensional problem of gas dynamics. Flow across Shock waves and Expansion waves. Flow through variable area ducts.

Unit III

Reacting Flows & Heat Transfer: Reactant and product mixtures, stoichiometry, absolute enthalpy, enthalpy of formation, chemical equilibrium, Gibbs function, Adiabatic Flame Temperature, shifting equilibrium and frozen flow assumptions. One-dimensional flows with friction and heat transfer. Conduction, convection & radiation heat transfer processes in one-dimensional gas flows.

Chemical Rockets: Gravity free flight of rockets. Performance Parameters (Total & Specific Impulse, Thrust Coefficient, Characteristic Velocity, Effective Exhaust Velocity, Combustion Parameter, Characteristic Length, Residence Time). Methods for evaluating performance parameters. Evaluation of chemical composition of combustion products and chamber temperature. Introduction to Solid and Liquid Propellants.

Unit IV

Solid Rocket Motor: Solid propellant burning mechanism and combustion models.
Burning rate of solid propellants under steady-state and transient conditions. Calculation of equilibrium chamber pressure under steady-state and transient conditions. Burning surface evolution. Erosive burning. Heat transfer and chamber wall temperature. Grain ignition and igniter assembly. Stability condition for steady-state operation of solid rocket motor.
Combustion instability and frequency of acoustic pressure oscillations in the motor.

Liquid Rocket Engine: Burning mechanism of liquid propellants. Combustion of mono & bi propellant systems. Droplet vaporization combustion model. Ignition delay. Pressure transients in liquid rocket motors. Combustion Instability. Heat transfer and cooling.
Design of liquid propellant engines (Propellant feed systems, Propellant tanks, Tank pressurization, Turbopumps, Engine integration)

Unit V

Hypersonic Air Breathing Propulsion: Aerothermodynamics of Ramjet & Scramjet Engines, Performance Measures, Compression, Expansion and Combustion systems.

Course Objectives:

- To impart knowledge about Missile Propulsion Systems.
- To introduce the fundamental of Chemical Rockets and Reacting Flows.
- To enable the students to understand the design and operation of Missile Propulsion Systems.

Course Outcomes

After completing this course, the students will be able to:
CO1: Learn about Missile Propulsion
CO2: Learn design and operation or various propulsion systems
CO3: Solve problems on Chemically Reacting Flows
CO4: Design and learn about Rocket Heat Transfer
CO5: Learn about Hypersonic Airbreathing Propulsion

Text Books

1. George P. Sutton, Rocket Propulsion Elements, Wiley-Interscience; 7th edition, 2000
2. M. J. Zucrow, Aircraft and Missile Propulsion, vol 1& 2, John Wiley, 1958
3. M. Barrere, Rocket Propulsion, Elsevier Pub. Co., 1960
4. M. J. Zucrow, Gas Dynamics, John Wiley & Sons; Volume 1, 1976
5. James E. A. John, Gas Dynamics, Prentice Hall, 3rd edition, 2006
6. P. Hill & C. Peterson, Mechanics & Thermodynamics of Propulsion, Prentice Hall, 2nd edition,1991

Reference Books

1. G. C. Oates, Aerothermodynamics of Gas Turbines and Rocket Propulsion, AIAA Education Series, 1989
2. W. Heiser, D. Pratt, D. Daley, U. Mehta, Hypersonic Airbreathing Propulsion, AIAA Education Series, 1994

Course Code	Course Name	L – T – P	Credits
AE 608	**UAV Design**	**3-1-0**	**4**

Course Objectives:

- To know about the basic terminology & design requirements
- To impart knowledge about the UAV design
- To enable the students to understand UAV system development

Course Contents

Unit I

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: Learn about the basic design requirements of an UAV
CO2: To gain knowledge about the aircraft design & its essentials
CO3: To know about the fundamental UAV system development

Text Books

1. J. Jayaraman, Unmanned Aircraft Systems: A Global View, DRDO, 2014.
2. Reg Austin, Unmanned Aircraft Systems, Wiley Publication, 2010.
3. Eugene L. Fleeman, Missile Design and System Engineering, AIAA Foundation Series, 2014.
4. John Anderson Jr., Aircraft Performance & Design, McGraw-Hill2014.

Reference Books

1. Daniel P. Raymer, Aircraft Design: A Conceptual Approach. AIAA Education Series, 2012

Course Code	Course Name	L – T – P	Credits
AE 609	**Guidance & Control for Aerospace Vehicles**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about the rigid body dynamics, transfer function and state space-based modelling of the system, guidance and navigation of the air vehicles.
- To introduce the fundamental concepts of autopilot systems, and servo systems.
- To enable the students to understand the guidance schemes.

Course Contents

Unit I
Mathematical Modelling: Rigid body force and moment equations, Aerodynamics forces and moments representation, linearization, Transfer function generation and stability analysis.

Unit II
Control: Aerodynamic and thrust vector control, polar and Cartesian control classical approach to control/ Autopilot design such as successive loop closer, three axes autopilot longitudinal, lateral and directional, three loop autopilot, Roll and lateral autopilot. Modern methods using state space approach, Controllability and Observability. Pole Placement techniques. Introduction to structure control interaction.

Unit III
Servo Systems: Hydraulic, Pneumatic & Electromechanical

Unit IV
Guidance: Missile & UAV guidance, Optimal guidance, Comparative study of PN guidance techniques, guidance laws for UAVs, path following, vision-based guidance, interception and avoidance; Collision detection and avoidance strategies. Introduction to cooperative control.

Unit V

Inertial Guidance: Intro, Inertial sensor, coordinate systems and transformations, Schuler tuning and gimbaled platform systems. INS –GPS integration, Data fusion.

Course Outcomes

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

CO1: Learn about the rigid body dynamic equations of motion of the UAVs and Guided Missiles, linearization of the nonlinear equations, generation of the transfer function and state-space model.

CO2: Learn about the concept and design of the different types of autopilots used in air vehicles. Analysis of the autopilots using control system tools.

CO3: Learn about the concept of the different types of servo systems.

CO4: Learn about the concept of different guidance schemes of guided missiles and UAVs.

Text Books

1. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.
2. P. Garnell, Guided Weapon Control Systems, 2nd Ed, Pergamon Press, London, 1980.
3. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.
4. K. Ogata, Modern Control Engineering, Prentice Hall of India, 1995.
5. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, New York, 2004.
6. P Zarchan, Tactical and Strategic Missile Guidance, Vol 199 of Progress in Astronautics and Aeronautics, AIAA, Reston, VA, 2002.
7. Rafael Yanushevsky, Guidance of Unmanned Aerial Vehicles, CRC Press, 2011.
8. Amitava Bose, Somnath Puri, Paritosh Banerjee, Modern Inertial Sensors and Systems, Prentice Hall of India, 2008.

Reference Books

1. Jay Gundlach, Designing Unmanned Aircraft Systems: A comprehensive Approach, AIAA Education Series, AIAA, 2012.
2. Randal W. Beard and Timothy W. McLain, Small Unmanned Aircraft Theory & Practice, Princeton University Press, 2012.

~~3.~~ Rasmussen, S., and Shima, T. (Eds.), UAV Cooperative Decision and Control: Challenges and Practical Approaches, SIAM Publications, 2008.

4. N. V. Kadam, Practical design of flight control systems for launch vehicles and missiles, Allied Publishers, 2009
5. Ian Moir, Allan Seabridge, Malcolm Jukes, Military Avionics Systems, Wiley, 2006.
6. Ching Fang Lin, Modern Navigation, Guidance and Control Processing, Prentice Hall, 1991

Course Code	Course Name	L – T – P	Credits
AE 610	**Missile Guidance & Control**	**3-1-0**	**4**

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.

Course Contents

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. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, New York, 2004.
2. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.
3. P Zarchan, Tactical and Strategic Missile Guidance, Vol 199 of Progress in Astronautics and Aeronautics, AIAA, Reston, VA, 2002.

4. P. Garnell, Guided Weapon Control Systems, 2nd Ed, Pergamon Press, London, 1980.
~~5.~~ B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987
6. K. Ogata, Modern Control Engineering, Prentice Hall of India, 1995.

Reference Books

1. R. Yanushevsky, Modern Missile Guidance, CRC Press, 2007.
2. N.A. Shneydor, Missile Guidance and Pursuit: Kinematics, Dynamics and Control, Horwood Publishing Ltd, 1998.
3. N. V. Kadam, Practical design of flight control systems for launch vehicles and missiles, Allied Publishers, 2009
~~4.~~ Ching Fang Lin, Modern Navigation, Guidance and Control Processing, Prentice Hall, 1991

Course Code	Course Name	L – T – P	Credits
AE 611	**UAV Guidance & Control**	**3-1-0**	**4**

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.

Course Contents

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, Designing Unmanned Aircraft Systems: A comprehensive Approach, AIAA Education Series, AIAA, 2012. 2. Rafael Yanushevsky, Guidance of Unmanned Aerial Vehicles, CRC Press, 2011. 3. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991. 4. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987. 5. Randal W. Beard and Timothy W. McLain, Small Unmanned Aircraft Theory & Practice, Princeton University Press, 2012.
Reference Books
1. Amitava Bose, Somnath Puri, Paritosh Banerjee, Modern Inertial Sensors and Systems, Prentice-Hall of India, 2008. 2. Ian Moir, Allan Seabridge, Malcolm Jukes, Military Avionics Systems, Wiley, 2006.

Course Code	Course Name	L – T – P	Credits
AE 612	**Experimental Aerodynamics**	**3-1-0**	**4**

Course Objectives:

- To understand the importance of experimental study in aerodynamics.
- To familiarize with different wind tunnels.
- To gain hands on experience on wind tunnel testing.
- To know in detail about the flow measurements: Pressure, Velocity, Temperature.
- To have hands on experience in pressure measurements, velocity measurements using Pitot-static probe, HWA and PIV
- To conduct flow visualization experiments.
- To measure force using Force/Torque sensor.
- To have hands on experience on data acquisition and processing.

Course Contents

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 moment: 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.
CO2: 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.
CO3: To use different pressure probes (Pitot-static probe, Pitot probe, 3-Hole probe, 5-Hole probe), Micromanometers, Hot-wire Anemometer (HWA) and Particle Image Velocimetry (PIV)
CO4: To understand the different flow visualization techniques. Conduct visualization experiments over different models in Subsonic Wind Tunnel and Hypersonic Table Top Shock Tunnel.
CO5: To use wind tunnel balance and to acquire force and moments of different Aircraft / UAV/Missile models.

Text Books

1. E. Rathakrishnan, Instrumentation, Measurements and Experiments in Fluids, CRC Press, Taylor & Francis Group, 2009.

Reference Books

1. Alan Pope & John J. Harper, Low-speed Wind Tunnel Testing, John Wiley & Sons, 1966.
2. Alan Pope & Kennith L. Goin, High-Speed Wind Tunnel Testing, John Wiley & Sons, 1965.
3. Bernhard H. Goethert, Transonic Wind Tunnel Testing, Pergamon Press, 1961.
4. Doeblin.E.O. Measurement systems Applications and design. 5th ed. McGrawHill, 2003
5. Cameron Tropea, Alexander L. Yarin, John F. Foss (Eds), Hand book of experimental fluid mechanics, Springer 2007.

Course Code	Course Name	L – T – P	Credits
AE 613	**Computational Aerodynamics**	**3-1-0**	**4**

Course Objectives:

- To understand the importance of computational study in aerodynamics.
- To familiarize with different computational software.
- To gain hands on experience on software used for aerodynamic analysis.
- To know in detail about the flow measurements: Pressure, Velocity, Temperature contours & vectors and in plotting the graphs respectively.

Course Contents

UNIT I

Introduction: Governing equations, model equations and classification of PDEs. Euler equations, Navier Stokes equations, Burger‘s equation & introduction to finite difference, finite element and finite volume methods.

UNIT II

Mesh: Basics of grid generation. Structured grid, unstructured grid

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

Boundary layer, shock-capturing, turbulence, aeroacoustic and aeroelastic computations.

Course Outcomes

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

CO1: To understand the importance of computational study in aerodynamics and to design the experiments for computational analysis.

CO2: To use different meshing software to create structured and unstructured mesh for various models for analysis.

CO3: To understand the different computational technique using different species model and to gain the knowledge of the specific models.

CO4: To gain the knowledge of SWBLI & aeroacoustics and their importance in the field of computational aerodynamics.

Text Books

1. C. Hirsch, Numerical Computation of Internal and External Flows, Volumes 1 & 2, Butterworth-Heinemann, Oxford, 2007
2. J. F. Thompson, B. K. Soni, N. P. Weatherill, Handbook of Grid Generation, CRC press, Taylor & Francis, 1998
3. E. F. Toro, Riemann Solvers and Numerical Methods for Fluid Dynamics, 3rd Ed, Springer, 2009
4. S. B. Pope, Turbulent Flows, Cambridge University Press, 2000

Reference Books

1. J. Blazek, Computational Fluid Dynamics: Principles and Applications, 2nd Ed, Elsevier, 2006

Course Code	Course Name	L – T – P	**Credits**
AE 614	**Structural Dynamics and Aeroelasticity**	3-1-0	**4**

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

Course Contents

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. D. H. Hodges & G. Alvin Pierce, Introduction to Structural Dynamics and Aeroelasticity, Cambridge University Press, 2002

Reference Books

2. Raymond L. Bisplinghoff, Holt Ashley & Robert L. Halfman, Aeroelasticity, Courier Dover Publications, 1996

Course Code	Course Name	L – T – P	Credits
AE 615	**Estimation and Tracking for Aerospace Application**	**3-1-0**	**4**

Course Objectives:

- To impart the knowledge about the offline and online estimation theory, various types of systems, Kalman filter, GPS.
- To introduce the fundamental concepts of deterministic and stochastic systems, process and measurement noise, LS, MLE, EKF.
- To enable the students to understand estimation of unknown parameters of a system.

Course Contents

UNIT I

Prolog: Historical Review of Estimation Theory, Application of Estimation Theory in Engineering. Application to Aerospace Problem (Offline and Online Estimation).
Review of probability theory and random variables: Vector and matrices, Probability and random process, Correlation function, Stationary process, Ergodic process, Power spectral density, Uniform distribution, Random distribution, Gauss Markov process, Random noise model.

UNIT II

Classical Offline Estimation Theory: Cramer-Rao lower bound, Minimum variance unbiased estimation, Least squares estimation, Method of Maximum likelihood Estimation (MMLE).

UNIT III

Online Estimation Theory:
a) Linear dynamical systems with random inputs: Linear stochastic systems, objectives. Continuous time linear stochastic systems: state space model and solution of continuous-time state-space representation. Discrete-time linear stochastic systems: state space model and solution of discrete-time state-space representation.
b) Linear estimation in linear static and dynamic systems: Linear minimum mean-squared error estimation. Principle of orthogonality. Least squares (LS) recursive estimation. Kalman filter (KF). Derivation. Matrix Riccati equations. Innovations process. Orthogonality issues. Gauss Markov Process
c) Estimation for kinematic models: Discretized continuous-time kinematic modes. Direct discrete kinematic models. LS and KF estimation for noiseless kinematic models. Steady state filters ((α, β)) tracker for noisy kinematic models. Process and Measurement Noise
d) Adaptive Nonlinear Estimation and maneuvering targets: Derivation of Extended Kalman Filter (EKF) Equations, Filter Divergence, Adaptive estimation of process and measurement noise, and its objectives. Different Kinematic Models, Innovations as a linear measurement of unknown input. Estimation of unknown input. Variable State Dimension approach. Comparison of adaptive estimation for Maneuvering Targets. Use of Extended Kalman Filter (EKF) for simultaneous state and parameter estimation.
e) Introduction to navigation applications: Complimentary filtering for navigation. Global Position Systems (GPS)-models, GPS positioning and its accuracy. State space model for navigation. Integrated navigation estimation. Centralized/distributed estimation fusion. Extended Kalman filter for navigation.

UNIT IV

Application of Estimation Theory to Aerospace Problem: Parameter Estimation of Spring mass damper system, Aerodynamic Parameter Estimation, Sensor bias estimation, Design of Radar and Seeker online Tracker

Note: Solving the assignment problems using MATLAB tool boxes is mandatory.
Course Outcomes
After completing this course, the students will be able to: **CO1:** Learn the various types of offline and online estimation methods. **CO2:** Learn about the static and dynamic systems, linear and nonlinear estimation methods. **CO3:** Solve the real-world problems of Aerospace Engg. using estimation theory.
Text Books
1. Dan Simon: Optimal State Estimation, Willey Inter science, First Edition, (2006). 2. Arthur Gelb: Applied Optimal estimation, The MIT Press, Sixteenth Reprint Edition, (2001). 3. Yaakov Bar-Shalom, X. Rong Li and Thiagalingam Kirubarajan: Estimation with Applications to Tracking and Navigation: Theory Algorithms and Software, John Wiley and Sons Inc. First Edition, (2001). 4. Frank L Lewis, Lihua Xie and Dan Popa: Optimal and Robust Estimation with an introduction to Stochastic Control Theory, CRC Press, Second Edition, (2008).
Reference Books
1. John H. Blakelock, Automatic Control of Aircraft and Missiles, Wiley, 1991 2. Anthony Lawrence, Modern Inertial Technology, Springer, 1998 3. Ching Fang Lin, Modern Navigation, Guidance and Control Processing, Prentice Hall, 1991 4. Amitava Bose, Somnath Puri, Paritosh Banerjee, Modern Inertial Sensors and Systems, Prentice Hall of India, 2008.

Course Code	**Course Name**	**L – T – P**	**Credits**
AE 616	**Nonlinear and Robust Control**	**3-1-0**	**4**

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.

Course Contents

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. J.J.E. Slotine and W. Li, Applied Nonlinear Control, Prentice-Hall, NJ, 1991. 2. H.K. Khalil, Nonlinear Systems, Prentice Hall, 2002. 3. H.K. Khalil, Nonlinear Control. Pearson Education, 2015. 4. S. Sastry, Nonlinear Systems: Analysis, Stability, and Control, Springer-Verlag New York Inc., 1999. 5. F. Lin, Robust Control Design: An Optimal Control Approach, Wiley, 2007.
Reference Books
1. John H. Blakelock, Automatic Control of Aircraft and Missiles, Wiley, 1991 2. P. Garnell: Guided Weapon Control Systems, Pergamon Press, London, 1980. 3. A. Sabanovic, L. Fridman, and S. Spurgeon, Variable Structure Systems: From Principles Implementation, IEE Control Series No. 66, 2004. 4. R. C. Dorf & R. H. Bishop, Modern Control Systems, Addison Wesley, 1998. 5. G.C. Goodwin, S.F. Graebe, and M.E. Salgado, Control System Design, Prentice Hall India, 2002. 6. H.K. Khalil, High-Gain Observers in Nonlinear Feedback Control. SIAM, 2017. 7. Jun Yang, Shihua Li, Wen-Hua Chen, Xisong Chen, Disturbance Observer-Based Control: Methods and Applications, CRC Press, 2014.

Course Code	Course Name	L – T – P	Credits
AE 617	**Avionics**	**3-1-0**	**4**

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.

Course Contents

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; Headdown 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. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, New Delhi, 2001.
2. Myron Kayton & Walter R. Fried, Avionics Navigation Systems, John Wiley & Sons, 1997.
3. Albert Helfrick, Principles of Avionics, Avionics Communications, 2009

Reference Books

1. John H. Blakelock, Automatic Control of Aircraft and Missiles, Wiley, 1991
2. Anthony Lawrence, Modern Inertial Technology, Springer, 1998
3. Ching Fang Lin, Modern Navigation, Guidance and Control Processing, Prentice Hall, 1991
4. Ian Moir, Allan Seabridge, Malcolm Jukes, Military Avionics Systems, Wiley, 2006.
5. Amitava Bose, Somnath Puri, Paritosh Banerjee, Modern Inertial Sensors and Systems, Prentice Hall of India, 2008.

Course Code	Course Name	L – T – P	Credits
AE 618	**Robotic Path Planning and Control**	**3-1-0**	**4**

Course Objectives:

- To impart the knowledge about the robot control system and its trajectory or path planning.
- To introduce the fundamental concepts of control system tools, manipulators, actuators, PID control scheme.
- To enable the students to understand the transfer function and state space model of robotic manipulators, and control scheme to handle them.

Course Contents

UNIT I

Time Response: Transient response and steady state error analysis of first and second order systems. Stability analysis Frequency response, Root locus analysis, Nyquist Criteria, design of compensators

state space method: Introduction to State space representation of dynamical systems. Solution of state equation. Controllability and observability, State feedback control, Pole placement techniques and design of observers.

UNIT II

Trajectory Planning: Definitions and Planning tasks, Joint Space techniques, Cartesian Space techniques, Joint Solace versus Cartesian Space Trajectory Planning –Obstacle Avoidance, Path Planning, Control of Manipulators: Open and Closed Loop Control, The Manipulator Control problem, Linear control Schemes, Characteristics of second order linear systems.

UNIT III

Linear Second Order SISO Model of a Manipulator Joint, Joint Actuators, Partitioned PD Control Scheme, PID Control Scheme, Computed Torque Control, Force Control of Robotic Manipulators, Description of force control tasks, Force control strategies, Hybrid Position/ Force Control, Impedance Force/ Torque Control.

Course Outcomes

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

CO1: Learn about the concept of first-order and second-order control system, transient and steady state response, stability analysis, root locus, compensator, pole placement technique, observer.

CO2: Learn the various types of the robotic manipulators and actuators.

CO3: Learn about the PID control scheme and its variants for controlling robotic manipulator.

Text Books

1. K. Ogata, Modern Control Engineering, 5th Edition, Prentice Hall, 2010.
2. M. W. Sponge and M. Vidyasagar, Robot Dynamics and Control, John Wiley & Sons, New York, USA, 2004.

Reference Books

1. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.
2. J.J.E. Slotine and W. Li, Applied Nonlinear Control, Prentice-Hall, NJ, 1991.

Course Code	Course Name	L – T – P	Credits
AE 619	**Signals and Systems**	**3-1-0**	**4**

Course Objectives:

- To impart the knowledge about the various types of signals, transformations, analysis, LTI systems, etc.
- To introduce the fundamental concepts of signal and its classifications, transformations.
- To enable the students to understand Laplace transform, Z-transform, Fast-Fourier transform etc.

Course Contents

UNIT I

Representation of Signal: Continuous and discrete time signals - definition and mathematical representation of basic signals- step, impulse, ramp and exponential signals. Classification of Signals Periodic, aperiodic, even, odd, energy and power signals. Deterministic and random signals, complex exponential and sinusoidal signals, periodicity.

Transformations: time scaling, time shifting. Determination of Fourier series representation of continuous time and discrete time periodic signals. Explanation of properties of continuous time and discrete time Fourier series. analysis

UNIT II

Analysis of continuous time signals and systems: Continuous time Fourier Transform and Laplace Transform: with of examples, basic properties-Linearity, Time Shift, frequency shift, time scaling, Parseval's relation and convolution in time and frequency domains. Basic properties continuous characterization time systems with examples: linearity, causality, time invariance, stability. Magnitude and Phase representation of frequency response of LTI systems. Analysis and of LTI systems using Laplace of impulse response and transfer function using Laplace transform. Z-transform, transform. Computation

UNIT III

Sampling theorem and Z-transform: Representation of continuous time signals by its samples. Sampling theorem. Reconstruction of a Signal from its samples. Aliasing. Z transform: definition of region of Properties of Z-transform with examples. convergence, examples, Poles and Zeros.

Inverse Z-transform: Inverse Z-transform using Contour integration. Residue Theorem. Power Series expansion and Partial fraction expansion. Relationship between z-transform and Fourier transform. Computation of Impulse, response and Transfer function using Z Transform.

UNIT IV

DFT and discrete time systems: Definition, properties and examples, Discrete time LTI systems. Properties: - linearity, causality, time invariance, stability, static and dynamic.

Characterization using difference equation. Block diagram representation, examples, Properties of convolution, interconnection of LTI Systems Causality and stability of LTI Systems. Realtime implementation issues and fast Fourier transform (FFT).

Design of Frequency Domain Filters. Design of low-pass, high-pass, notch filters.

Note: Solving the assignment problems using MATLAB tool boxes is mandatory.

Course Outcomes
After completing this course, the students will be able to: **CO1:** Learn about the concept of continuous and discrete type of signals, its classifications and transformations. **CO2:** Solve the problems of Laplace transform, Z-transform, Fast Fourier transform. **CO3:** Learn about the LTI system, its representation in continuous and discrete form, various types of filters.
Text Books
1. Vinay Ingle and John G Proakis: Digital Signal Processing Using MATLAB, Congage Learning, Third Edition, (2012). 2. A V Oppenheim, A S Willsky and S Hamid: Signals and Systems, Prentice Hall, Second Edition, (1996).
Reference Books
1. E Oran Brigham: The Fast Fourier Transform and Its Applications, Prentice Hall, First Edition, (1988). 2. A V Oppenheim, R W Schafer and John R Buck: Discrete Time signal Processing, Prentice Hall, Second Edition, (1999).

Course Code	Course Name	L – T – P	Credits
AE 620	**Optimal Control with Aerospace Applications**	**3-1-0**	**4**

Course Objectives:

- To impart the knowledge about the optimization, linear and nonlinear programming, optimal control of continuous time system.
- To introduce the fundamental concepts of the various optimization techniques/methods.
- To enable the students to formulate the optimization problem of the continuous time system.

Course Contents

UNIT I

Introduction and review of basic concepts: Introduction, motivation and overview, matrix algebra, review of numerical methods.

UNIT II

Static optimization: Unconstrained optimization, constrained optimization – Lagrange multiplier, equality constraints, inequality constraints, neighboring optimum solutions. Numerical solutions. Linear programming problems. Nonlinear programming, Kuhn Tucker condition, Direct optimization by gradient methods. Solutions of static optimization problems for both constrained and unconstrained case.

UNIT III

Optimal control of continuous time system by indirect method: Optimal control through calculus of variation, Euler Lagrange necessary condition, Legendre necessary condition, Jacobi necessary condition, Bolza problem, Mayer problem, Lagrange problem, some sufficiency conditions to the simplest problem, Transversability conditions, Complete optimal control formulation using calculus of variation. Fixed terminal time and free terminal time problem, Continuous-time linear quadratic regulator (LQR). Steady-state closed-loop control and suboptimal feedback, Numerical solution of two-point boundary value problem.

UNIT IV

Optimal control of continuous time system by direct method: Simple shooting method, Multiple shooting method, Collocation method, Pseudo spectral methods.

UNIT V

Comparison of direct and indirect method of solution: Solution of Brachistochrone problem, Flight Vehicle trajectory optimization using both methods with in flight path constraints and terminal constraints. Advantages and disadvantages of indirect and direct methods.

Note: Solving the assignment problems using MATLAB tool boxes is mandatory

Course Outcomes

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

CO1: Learn the various types of the optimization and programming methods and solving their respective problems.

CO2: Learn to formulate an optimal control problem for a continuous time system and finding optimal solution.

CO3: Learn to solve the various types of optimal problems and study the flight vehicle trajectory problem with the constraints.

Text Books

1. R Venkatraman: Applied Optimization with MATLAB Programming, John Willey and Sons, Second Edition, (2004).
2. S S Rao: Engineering Optimization, Theory and Practice, John Willey and Sons, Fourth Edition, (2009).
3. Kalyanmoy Deb: Optimization for Engineering Design (Algorithms and Examples), Eastern Willey Edition, Second Edition, (2012).
4. John T Betts: Practical Methods for Optimal Control and Estimation Using Nonlinear Programming, SIAM Publishers, Second Edition, (2010).
5. Frank L Lewis, D L Vrabie and V L Syrmos: Optimal Control, John Willey and Sons, Third Edition, (2012).

Reference Books

1. B. D. O. Anderson and J B. Moore, Optimal Control: Linear Quadratic Methods, Dover Publications Inc., 2007.
2. D. E. Kirk, Optimal Control Theory: An Introduction, Dover Publications Inc., 2004.
3. R. F. Stengel, Optimal Control and Estimation, Dover Publications Inc., 2003.
4. A R Tannenbaum, B A Francis and J C Doyle, Feedback Control Theory, Dover Publications Inc., 2009.
5. S. Skogestad, I. Postlethwaite, Multivariable Feedback Control: Analysis and Design, Wiley-Interscience, 2005.

Course Code	Course Name	L – T – P	Credits
AE 621	**Advanced Missile Guidance**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about the Seeker, Guidance Laws, INS, GPS, etc.
- To introduce the fundamental concepts of Inertial and Global Positioning based Navigation, and their integration.
- To enable the students to understand various types of PN Guidance laws and seekers for guided missiles.

Course Contents

UNIT I

Inertial Navigation Systems: Kinematics, Angular Velocity and torque equations of gimballed system, errors in INS; Strap Down Inertial Navigation System: Inertial Alignment System, flow diagram and direction cosine computation algorithm of SDINS.

UNIT II

Global Positioning System: Introduction, modes of operations, signals and codes, position fixing, Differential GPS and GPS coordinate transformation. Kalman filtering and integration of GPS and INS.

UNIT III

Missile Guidance loop design studies, Guidance loop model, Normalised homing time and normalised miss distance, variants of PN Laws, Optimal guidance Law, performance comparison of different guidance Laws.

UNIT IV

Guided missile design: Top-down approach; Guidance & control systems specifications, specifications on aerodynamics, roll dynamics & rolling moment gradient limit, Autopilot & it's hardware. Requirements, Seeker specifications- Range, Antenna & Radome slope error specs RF & IR Seeker based Guidance, Seeker angle tracking and stabilization systems – Isolation & Decoupling; Nominal scheme & Decoupling loop scheme-based approach for guidance – Generic performance comparison; LOS reconstruction approach for faster cost-effective homing guidance, performance comparisons of different schemes through 3-DOF simulations. Radome error modelling, Guidance & control system with radome error-static effects and dynamic effects, Deleterious effects of radome error on guidance, Radome error characterization and compensation

UNIT V

Seeker estimator: Inside and outside seeker mechanization, performance comparison, eclipsing effects & performance-Multiple PRF seeker

Course Outcomes

After completing this course, the students will be able to:
CO1: Learn about the concept of INS, GPS, Kalman filter, Integration of INS and GPS.
CO2: Learn about the LOS, NGC loop, seeker, guidance laws, autopilot, etc.
CO3: Design and analysis of the navigation, guidance and control loop for the guided missile.

Text Books
1. P. Garnell, Guided weapon control systems, 2nd ed, pergamon press, London, 1980 2. P. Zarchan, Tactical & Strategic Missile Guidance, American Institute of Aeronautics and Astronautics, 2007 3. G. M. Siouris, Missile Guidance and Control Systems, Springer, 2004 4. John H. Blakelock, Automatic Control of Aircraft and Missiles, Wiley, 1991 5. Merill I. Skolnik, Introduction to Radar system, Tata Mc Hill, New Delhi, 2001
Reference Books
1. Anthony Lawrence, Modern Inertial Technology, Springer, 1998 2. Ching Fang Lin, Modern Navigation, Guidance and Control Processing, Prentice Hall, 1991 3. R. Yanushevsky, Modern Missile Guidance, CRC Press, 2007. 4. N. A. Shneydor, Missile Guidance and Pursuit: Kinematics, Dynamics and Control, Horwood Publishing Ltd, 1998. 5. N. V. Kadam, Practical design of flight control systems for launch vehicles and missiles, Allied Publishers, 2009 6. Amitava Bose, Somnath Puri, Paritosh Banerjee, Modern Inertial Sensors and Systems, Prentice Hall of India, 2008.

Course Code	Course Name	L – T – P	**Credits**
AE 622	**Ducted Rocket and Combustion**	3-0-1	**4**

Course Objectives:

- To impart knowledge about Ducted Propulsion Systems.
- To introduce the fundamental Ramjets and Integrated Ram Rockets.
- To introduce students to experimental techniques in Combustion & Propulsion

Course Contents

Unit I

Ramjet and integral rocket ramjet: Thrust and thrust coefficients, effective jet velocity, Combustion efficiency, Classification and comparison of IRR propulsion system. Two-phase nozzle flows, Scramjet, Solid fuel ramjets, Advances in Propulsion Technology.

Unit II

Experimental techniques for rocket testing: General layout of solid, liquid, and IRR Thrust stand, auxiliaries, safety measures. Thrust, pressure, flow and temperature measurements. Evaluation of tests.

Unit III

Combustion: Pre-mixed flames - flame speed, inflammability limits, one dimensional flame propagation, Diffusion flames, Detonation and deflagration.

Course Outcomes

After completing this course, the students will be able to:
CO1: Learn about Ducted Propulsion Systems like Ramjet and IRR
CO2: Design experiments on Combustion and Ducted Propulsion Systems
CO3: Solve problems in Combustion

Text Books
1. M.J. Zucrow and J.D. Hoffman, Gas dynamics, Vol. I, John Wiley and sons, New York, 1976 2. M.J. Zucrow, Aircraft and Missile Propulsion, Vol II, John Wiley and Sons, New York, 1958 3. K. Kuo, Principles of Combustion, 2nd Ed, John Wiley & Sons, 2005
Reference Books
1. I. Glassman, Combustion, Ist Ed, Academic Press, San Diego, California 1997

Course Code	Course Name	L – T – P	Credits
AE 623	**Experimental Methods in Fluid Mechanics**	**3-1-0**	**4**

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 hands on experience on water and wind tunnel & their principle used for the measurements in turbo machineries.
- To know in detail about the flow visualization, data acquisition & processing techniques.

Course Contents

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.

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).

Temperature Measurements: Thermometers, Thermocouples, Pyrometers, Planar laser-induced fluorescence (PLIF)

Force and Moment Measurements: Strain gauges, Piezoelectric transducers, Accelerometers, Force/torque sensors, External and Internal wind tunnel balances.

Shear stress measurements: Floating element method, momentum integral method, Preston tube, Fence Technique, Heat Transfer Gauge.

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 III

Measurements in Turbo machineries, Wind Tunnel Testing; Water Tunnels Testing

Unit IV
Flow visualization: Wool tufts, dyes, smoke wire, smoke rake, smoke tunnel, shadow graph, Schlieren, particles, bubbles, Fluorescence. 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: To use different instruments & their principles for measuring the basic fluid dynamic characteristics such as pressure, velocity, temperature, force & moment etc. & its measurements
CO3: To understand the usage of different tunnels (wind & water) used in turbomachinery measurements.
CO4: To gain the knowledge of flow visualization technique and data acquisition & processing methods

Text Books

1. E Rathakrishnan, Instrumentation, Measurements and Experiments in Fluids

Reference Books

1. Cameron Tropea, Alexander L. Yarin, John F. Foss (Eds), Hand book of experimental fluid mechanics, Springer 2007
2. Robert A. Granger, Experiments in Fluid Mechanics, Holt, Rinehart and Winston, Inc,1988
3. Raffel, M., Willert, C.E., Scarano, F., Kähler, C., Wereley, S.T., Kompenhans, J., Particle Image Velocimetry, Springer 2018

Course Code	Course Name	L – T – P	Credits
AE 624	**Aircraft Assembly, Inspection & Tests**	**3-1-0**	**4**

Course Objectives:
- To impart knowledge about the Aerospace Manufacturing.
- To introduce the fundamental concepts of Engineering drawing
- To enable the students to understand various materials & resources used in aircraft assembly
- To gain the knowledge about the various concepts of assembly & maintainence

Course Contents

Unit I
Aerospace manufacturing: A Systems approach and standards, Incoming inspection, documentation, record keeping, identification & traceability, safety in 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: Different materials & consumables. Jigs and fixtures, Calibration, Jig less assembly, case studies. Manual vrs automated assembly.

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 30 assembly, Bearings, 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, Inspection, Functional Tests, Certification, Boroscopy/Fibroscopy, Case studies. Care during maintenance, Statistical Process controls/ Process capability, Control charts & Trouble shooting. Painting, Coating, Surface treatments and corrosion prevention.

Course Outcomes

After completing this course, the students will be able to:
CO1: Learn the various approach of aircraft standards & safety followed in the assembling of the aircraft
CO2: Learn how 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. Aircraft Production Technology and Management: Keshu S C and Ganapathi K K, Interline Publisher
2. Aircraft Production Technology, Douglas F. Horne, ISBN: 9780521265539, July 1986
3. Aircraft Manufacturing and Assembly, Branko Sarh, James Buttrick, Clayton Munk, Richard Bossi, Springer Berlin Heidelberg
4. Aerospace Manufacturing Processes – 26 August 2016, Pradip K. Saha
5. Airbus A380 Owner's Workshop Manual, 2005 to present, Robert Wicks, 2017

Reference Books

Course Code	Course Name	L – T – P	Credits
AE 625	**Hypersonic Flow**	**3-1-0**	**4**

Course Objectives:
- To understand the importance of basics of hypersonic flow & its governing equations
- To familiarize with inviscid hypersonic flow & its flow fields
- To familiarize with viscid hypersonic flow & its experimental interactions
- To get hands on experience on hypersonic wind tunnel & data acquisition technique

Course Contents

Unit I
Introduction: To familiarize with inviscid hypersonic flow & its flow fields

Unit II
Inviscid hypersonic flow: Shock wave and expansion wave relations, local surface inclination methods, modified Newtonian Law, Newtonian theory, tangent wedge or tangent cone and shock expansion methods, Calculation of surface flow properties. Approximate methods for hypersonic inviscid flow field. Exact methods for hypersonic inviscid flow field.

Unit III
Viscous hypersonic flow: Navier–Stokes equations, boundary layer equations for hypersonic flow, hypersonic boundary layer, hypersonic boundary layer theory and non-similar hypersonic boundary layers, hypersonic aerodynamic heating, entropy layers effects on aerodynamic heating. Strong and weak viscous interactions, hypersonic shockwaves and boundary layer interactions

Unit IV
Hypersonic test facilities and measurements: Shock tubes, hypersonic wind tunnels

Course Outcomes

After completing this course, the students will be able to:
CO1: To understand the importance of basic hypersonic flows
CO2: To gain knowledge about inviscid hypersonic flow
CO3: To understand viscous hypersonic flow
CO4: To gain the hands on experience on shock tubes and hypersonic shock tunnels

Text Books

1. John. D. Anderson. Jr, Hypersonic and High Temperature Gas Dynamics‖, 2nd edition, AIAA education series, 2006.
2. John J. Bertin, Hypersonic Aerothermodynamics‖, AIAA education series, 1994.
3. John. D. Anderson. Jr, Modern Compressible Flow: With Historical Perspective‖, 3rd edition, Mcgraw Hill, 2004

Reference Books

1. John J. Bertin, Russell M. Cummings, Aerodynamics for Engineers, 6 thedition,Prentice Hall, 2013 2. Ernst Heinrich Hirschel, Basics of Aerothermodynamics‖, 2nd edition, Springer, 2015 6. R. N. and L. F. Crabtree Cox, Elements of Hypersonic Aerodynamics‖ Academic Press, 1965
2. Wallace D. Hayes and Ronald F. Probstein, Hypersonic Flow Theory‖, Academic Press Company, 1959
3. 4. Wallace D. Hayes and Ronald F. Probstein, Hypersonic Inviscid Flow‖, Dover Publications,2004 5. W. Hankey, Re-Entry Aerodynamics‖, AIAA education series, 1988

Course Code	Course Name	L – T – P	Credits
AE 626	**Compressible Fluid Flow**	**3-1-0**	**4**

Course Objectives:

- To gain the knowledge on concepts of Aerodynamics, fluid mechanics and thermodynamics
- To familiarize with the different types of flows (sub, trans, super & hypersonic) & its principle

Course Contents

Unit I: Introduction: Basic concepts of Aerodynamics, Fluid Mechanics & Thermodynamics

Unit II: Subsonic compressible flows: Linearized Velocity Potential Equation, Linearized Pressure Coefficient, Linearized Subsonic Flow, Improved Compressibility Corrections, Critical Mach Number.

Unit III: Transonic flows: Physical and Theoretical aspects of transonic flows, Solutions of the Small Perturbation Velocity Potential Equation, Solutions of the Full Velocity Potential Equation, Solutions of the Euler Equations.

Unit IV: Supersonic flows: Normal Shock, Oblique Shock and Expansion waves, Source of Oblique Waves, Oblique Shock Relations, Supersonic Flow over Wedges and Cones, Shock Polar, Regular Reflection from a Solid Boundary, Intersection of Shocks waves, Mach Reflection, Detached Shock Wave in Front of a Blunt Body, Three-Dimensional Shock Wave, Prandtl-Meyer Expansion Waves, Shock-Expansion Theory, Shock boundary layer interactions.

Unit V: Hypersonic Flows: Hypersonic Shock Wave Relations, A Local Surface Inclination Method: Newtonian Theory, Mach Number Independence, The Hypersonic Small-Disturbance Equations, Hypersonic Similarity Compressible flow test facilities and measurements

Course Outcomes

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

CO1: To understand the basic concepts of Aerodynamics, Fluid Mechanics & Thermodynamics

CO2: To gain knowledge about the different types of flows and its principle in detail

Text Books

1. John D. Anderson, Modern Compressible Flow: With Historical Perspective, 3rd Ed, McGraw Hill, New York, 2004.
2. Michel A. Saad, Compressible Fluid Flow, 1992
3. John D. Anderson, Hypersonic and High Temperature Gas Dynamics, American Institute of Aeronautics & Astronautics, New York, 2000.
4. Roelof Vos and Saeed Farokhi, Introduction to transonic aerodynamics: 110 (Fluid Mechanics and Its Applications), Springer, 2015

Reference Books

1. John D. Anderson, Fundamentals of Aerodynamics, 4th Edition, McGraw Hill, 2006.

2. John D. Anderson, Hypersonic and High Temperature Gas Dynamics, McGraw Hill, 2006	

Course Code	Course Name	L – T – P	Credits
AE 627	**Flow Stability & Turbulence**	**3-1-0**	**4**

Course Objectives:

- To know the basic concepts of the flow stability and its mechanisms
- To familiarize with the concepts of turbulence & its dynamics
- To gain the knowledge of flow modelling and simulation

Unit I

Introduction: Mechanism of flow instability, fundamental concepts of flow stability,

Unit II

Stability of parallel shear flow, Stability of Boundary Layer flow, Linear & Non-Linear stability, Transition. Introduction to turbulence, turbulent transport, dynamics of turbulence, free shear flows, wall bounded flows

Unit III

Statistical description of turbulence, spectral dynamics, turbulent flow modelling and simulation.

Course Outcomes

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

CO1: To understand the basic concepts of flow stability and its mechanism

CO2: To gain knowledge about turbulence & it's dynamics

CO3: To design & simulate turbulent models

Text Books

1. Henk Tennekes & John Lumley, A First Course in Turbulence, MIT Press (MA), 1972.
2. Stephen B. Pope, Turbulent flow, Cambridge University Press, 2000.

Reference Books

1. P. G. Drazin & W. H. Reid, Hydrodynamic Stability, 2nd Ed., Cambridge University Press, 2004.
2. Peter J. Schmid & D. S. Henningson, Stability and Transition in Shear Flows, Springer, 2001.

Course Code	Course Name	L – T – P	Credits
AE 628	**Missile Aerodynamics**	**3-1-0**	**4**

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
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, Missile Aerodynamics, McGraw Hill, 1960
2. Chin S S, Missile Configuration Design, McGraw-Hill, 1961
3. Eugene L. Fleeman, Missile Design and Systems Engineering, AIAA Education Series, 2000

Reference Books
1. John D. Anderson, Hypersonic and High Temperature Gas Dynamics, American Institute of Aeronautics & Astronautics, New York, 2000. 2. John D. Anderson, Modern Compressible Flow: With Historical Perspective, 3rd Ed, McGraw Hill, New York, 2004. 3. John D. Anderson, Fundamentals of Aerodynamics, 4th Edition, McGraw Hill, New York, 2006. 4. E. L. Houghton and P. W. Carpenter, Aerodynamics for Engineering Students, 5thEdition, Butterworth-Heineman, Oxford, 2003

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 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 endeavours to become Centre of Excellence in Armaments/Combat vehicles, Marine engineering, Mechanical Systems Design and Robotics"

Mission of the Department:
To impart advanced training, update knowledge, and develop skillset 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 and Robotics.
PEO2: Students should be capable to undertake R&D, inspection, testing and evaluation of equipment/systems of Combat vehicles, Armaments, Marine and Robotic 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 nuclear enggetc, 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 Engineering of a recognised Institute/University.

Organization: M. Tech Mechanical Engineering with specialisation Marine Engineering 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 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, 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 Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 602	Advanced Mechanics of Materials	3	1	4
2	ME 603	Fluid Flow and Heat Transfer	3	1	4
3	ME 641	Warship Transmission & Tribology	3	1	4
4	ME 609	Mechanical Vibrations	3	1	4
5	ME 643	Ship Dynamics & Marine Systems	3	1	4
6	AM 607	Mathematics for Engineers	3	1	4
7	PGC 601	Research Methodology and IPR	2	0	2
		Total	**20**	**6**	**26**

Semester II

Sl. No.	Course Code	Course	Credits L	Credits T/P	Total Credits (*)
1	ME 644	Marine Diesel &Steam Engines	3	1	4
2	ME 645	Marine Gas Turbines	3	1	4
3	--	Department Elective-I	3	1	4
4	--	Department Elective-II	3	1	4
5	--	Elective III	3	1	4
6	--	Elective IV	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	**20**	**6**	**26**

Semester III

Sl. No.	Course Code	Course	Credits L	Credits T/P	Total Credits (*)
1	ME 651	M.Tech. Dissertation Phase I	14		14
		Total	**14**		**14**

Semester IV

Sl. No.	Course Code	Course	Credits L	Credits T/P	Total Credits (*)
1	ME 652	M.Tech. Dissertation Phase II	14		14
		Total	**14**		**14**

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

List of Department Electives (I & II)

Sr. No.	Course Code	Course Title
1	ME 607	Computational Fluid Dynamics
2	ME 608	Finite Elements Methods
3	ME 627	Fatigue, Fracture and Failure Analysis
4	ME 630	Design of Machinery
5	ME 631	Product Design and Development
6	ME 637	Design of Pressure Vessels
7	ME 646	Nuclear Reactor Engg.
8	ME 654	Convective Heat & Mass Transfer

9	ME 660	Heat Exchanger Design

List of Electives (III & IV)

Sl. No.	Course Code	Course Name
1.	ME 604	Advanced Materials and Processing
2.	ME 608	Finite Elements Methods
3.	ME 611	Design for Manufacturability
4.	ME 615	Trials & Evaluation of Weapon Systems
5.	ME 616	Thermal Management of Defence Equipment
6.	ME 617	Kinematics and Dynamics of Machinery
7.	ME 618	Composite Structures
8.	ME 619	Tribology for Design
9.	ME 627	Fatigue, Fracture and Failure Analysis
10.	ME 628	Design of Hydraulic and Pneumatic Systems
11.	ME 629	Design of Experiments
12.	ME 630	Design of Machinery
13.	ME 631	Product Design and Development
14.	ME 632	Design Optimization
15.	ME 633	Mechanical behavior of materials
16.	ME 634	Experimental Stress Analysis
17.	ME 635	CAD
18.	ME 636	MEMS: Design, Fabrication and Characterization
19.	ME 637	Design of Pressure Vessels
20.	ME 642	Automatic Control Systems
21.	ME 654	Convective Heat & Mass Transfer
22.	ME 655	Performance Testing and Instrumentation
23.	ME 657	Marine Hydrodynamics
24.	ME 658	Additive Manufacturing
25.	ME 659	Rapid Prototyping
26.	ME 660	Heat Exchanger Design
27.	AM 602	Mathematical Modeling & System Analysis
28.	AM 603	Adv Optimization Techniques
29.	AM 604	Advanced Statistical Techniques
30.	AM 623	Machine Learning
31.	AM 624	Advanced Numerical Methods
32.	TM 602	R&D Management
33.	TM 603	Project Management
34.	TM 604	Strategic Management
35.	TM 609	System Engineering
36.	MS 601	Introduction to Materials

37.	MS 607	Design of Materials
38.	MS 606	Advanced Physical and Mechanical Metallurgy
39.	MS 612	Non Destructive Evaluations
40.	MS 611	Advanced Functional Materials
41.	MS 613	Advanced Steel Technology
42.	AC 603	Thermodynamics and Combustion Process
43.	AP 610	Nanotechnology
44.	CE696A	Artificial Intelligence & DSS
45.	CE699	Internet of Things
46.		Open Electives from other departments

Notes:

1. Department has to decide which subjects should be offered as Elective I, II in the Semester II.
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 system.

The objective of 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 system. This can be achieved by teaching a candidate different range of subjects for enhancing their analytical skills related to Machine design. Other 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, invited experts from reputed institutions and industries.

Eligibility: Bachelor’s Degree in Mechanical/Production/Automobile/Mechatronics/Metallurgy and materials/Mining/Aerospace Engineering of a recognized Institute/University.

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 specialisation in Mechanical System Design is a four-semester programme. In the first semester, there are six courses. 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 third semester, M. Tech. (phase I) dissertation is there and in 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, 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 Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 602	Advanced Mechanics of Materials	3	1	4
2	ME 603	Fluid Flow and Heat Transfer	3	1	4
3	ME 604	Advanced Materials and Processing	3	1	4
4	ME 609	Mechanical Vibrations	3	1	4
5	ME 618	Composite Structures	3	1	4
6	AM 607	Mathematics for Engineers	3	1	4
7	PGC 601	Research Methodology and IPR	2	0	2
		Total	**20**	**6**	**26**

Semester II

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 630	Design of Machinery	3	1	4
2	ME 631	Product Design and Development	3	1	4
3	--	Department Elective-I	3	1	4
4	--	Department Elective-II	3	1	4
5	--	Elective-III	3	1	4
6	--	Elective-IV	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	**20**	**6**	**26**

Semester III

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 651	M.Tech. Dissertation Phase I	14		14
		Total	**14**		**14**

Semester IV

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 652	M.Tech. Dissertation Phase II	14		14
		Total	**14**		**14**

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

List of Department Electives (I & II)

Sr. No.	Course Code	Course Title
1	ME 608	Finite Elements Methods
2	ME 619	Tribology for Design
3	ME 627	Fatigue, Fracture and Failure Analysis
4	ME 629	Design of Experiments

List of Electives (III & IV)

Sr. No.	Course Code	Course Title
1	ME 607	Computational Fluid Dynamics
2	ME 608	Finite Elements Methods
3	ME 611	Design for Manufacturability
4	ME 617	Kinematics and Dynamics of Machinery
5	ME 619	Tribology for Design
6	ME 627	Fatigue, Fracture and Failure Analysis
7	ME 628	Design of Hydraulic and Pneumatic Systems
8	ME 629	Design of Experiments
9	ME 632	Design Optimization
10	ME 633	Mechanical behavior of materials
11	ME 634	Experimental Stress Analysis
12	ME 635	CAD
13	ME 636	MEMS: Design, Fabrication and Characterization
14	ME 637	Design of Pressure Vessels
15	ME 654	Convective Heat & Mass Transfer
16	ME 658	Additive Manufacturing
17	ME 659	Rapid Prototyping
18	ME 660	Heat Exchanger Design
19	ME 662	CAM
		Open Electives from other departments

Notes:

1. Department has to decide which subjects should be offered as Elective I, II in the Semester II.
2. Practice school (Optional) of 4 weeks duration during Summer Vacation.

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 in Mechanical/ Production/ Automobile/ Materials/ Metallurgy/ Mechatronics Engineering disciplines from recognized university.

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 specialisation in Armament and Combact 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.

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	Credits		Total Credits (*)
			L	T/P	
1	ME 601	Armament & Combat vehicles-I	3	1	4
2	ME 602	Advanced Mechanics of Materials	3	1	4
3	ME 609	Mechanical Vibrations	3	1	4
4	ME 604	Advanced Materials and Processing	3	1	4
5	ME 605	Introduction to Combat Systems	3	1	4
6	AM 607	Mathematics for Engineers	3	1	4
7	PGC 601	Research Methodology and IPR	2	0	2
		Total	**20**	**6**	**26**

Semester II

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 610	Armament & Combat Vehicles-II	3	1	4
2	ME 613	Armour Protection Systems	3	1	4
3	--	Department Elective-I	3	1	4
4	--	Department Elective-II	3	1	4
5	--	Elective-III	3	1	4
6	--	Elective-IV	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	**20**	**6**	**26**

Semester III

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 651	M.Tech. Dissertation Phase I	14		14
		Total	**14**		**14**

Semester IV

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	ME 652	M.Tech. Dissertation Phase II	28**		14
		Total	**28**		**14**

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

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

List of Electives (III & IV)

S. No.	Course Code	Course Name
Elective I and II		
	ME 607	Computational Fluid Dynamics (CFD)
	ME 608	Finite Element Methods (FEM)
	ME 611	Design for Manufacturability
	ME 612	Modeling and Simulation of Military vehicles
	ME 654	Convective Heat and Mass Transfer
	ME 614	Unmanned Ground Vehicles
	ME 615	Trials & Evaluation of Weapon Systems
	ME 616	Thermal Management of Defence Equipment
	ME 617	Kinematics and Dynamics of Machinery
	ME 618	Composite Structures
	ME 619	Tribology for Design
	ME 620	High Energy Material Technology
	ME 621	Dynamics & Armament Mechanisms
	ME 622	Ballistics of bombs and projectiles
	ME 623	Design of ordnance, basic structure and super structure
	ME 624	Small arms and cannons
	ME 625	Combat Vehicle Technology
	ME 626	Vehicle Dynamics
	ME 627	Fatigue, Fracture and Failure Analysis
	ME 628	Design of Hydraulic and Pneumatic Systems
	ME 629	Design of Experiments
	ME 630	Design of Machinery
	ME 642	Automatic Control System
		Open Electives from other departments

Notes:

1. Department has to decide which subjects should be offered as Elective I, II in the Semester II.
2. Practice school (Optional) of 4 weeks duration during Summer Vacation.

Course Code	Course Name	L-T-P	Credits
ME 601	**Armament and Combat Vehicles-I**	**3-1-0**	**4**

Course Objectives:

- **To impart fundamental and advanced knowledge of Combat Vehicle System**
- **To enable the students to understand various topics of the subject such as** Power packs, Transmission and Steering etc.

Course Contents

Unit I: Introduction to Automotive systems: Vehicle Classification – On-Road (multi axle, trailer), Off Road (wheeled, tracked), Amphibious; Systems of Automotive Vehicles - Chassis / Body of vehicle; Power plant, Transmission; Additional design considerations: Vehicle stability, Modularity, Transportability to area of operation (by road, rail or by air), logistics for operation.

Unit II: 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.

Unit III: 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 IV: 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 V: 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.

Course Outcome:
CO1: Understand the basics of Vehicle Classification, Systems of Automotive Vehicles, Stability, Modularity, Transportability, Critical dimensions, Terramechanics, Power packs, Transmission, Steering and gear system, human response to vibrations of combat vehicles.
CO2: Understand the off road and amphibious vehicle design, Chassis design, different type of power packs, transmission system, quarter car and half car models. Evaluate Terramechanics behavior, relative performance of power packs, Hydrokinetic and Hydro static Drives. Apply constitutive equations for Terramechanics analysis and calculations of critical dimensions and evaluate engineering constants and analyze combat vehicle behavior at macro level.
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 proposing solution to the existing problems persisting in current inventory of combat vehicles.

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 Code	Course Name	L-T-P	Credits
ME 602	**Advanced Mechanics of Materials**	**3-1-0**	**4**

Course Objectives:

- **To impart fundamental and advanced knowledge of the subject**
- **To enable the students to understand various topics of the subject such as elasticity, energy methods, Asymmetrical Bending of beams etc.**

Course Contents

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.

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.

Course Outcome:

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.

Text Books/References:

1. Theory of Elasticity, 1970, Timoshenko SN &GoodierJN, McGraw Hill.
2. Advanced Mechanics of Materials, 2nd Ed., 1998 Cook RD &YoundWC, 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 Code	Course Name	L-T-P	Credits
ME 603	**Fluid Flow & Heat Transfer**	**3-0-1**	**4**

Course Objectives:

- **To introduce concepts of fluid mechanics.**
- **To impart fundamental and advanced knowledge of the subject**
- **To enable the students to understand various topics of the subject such as Heat Transfer, boundary layer theory etc.**

Course Contents

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, 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, Blausius 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 flows, 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.

Practice:

- 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.

Course Outcome:
CO1: Understand and review of 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 process, 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.

Text books:

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 (10^{th} Edition, McGraw Hill Education)

References:

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

Course Code	Course Name	L-T-P	Credits
ME 604	**Advanced Materials and Processing**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Advanced Materials and Processing**
- **To impart fundamental and advanced knowledge of the subject**
- **To enable the students to understand various topics of the subject such as SMA, Compositematerials, er and MR materials etc.**

Course Contents

Unit I: Introduction of advanced materials and its manufacturing processes for engineering applications. Piezoelectric materials (PZT)- Piezoelectric effect, Di-electric hysterisis, piezoelectric constants, piezoelectric charge constants, dynamic behaviour of PZT transducers, piezoelectric materials and manufacturing techniques (stability, poling and depolarisation).

Unit II: Shape memory alloys (SMA)- Shape memory effect and the metallurgical phenomenon of SMA, Temperature assisted shape memory effect, Visco-elastic behaviour, magnetic shape memory effect. Various shape memory alloys. Manufacturing technology of SMAs.

Unit III: Electro rheological (ER) and magneto-rheological (MR) materials- Characteristics of ER and EM fluids. ER and EM materials.

Unit IV: Composite materials- Design and manufacturing of polymer matrix, metal matrix and ceramic matrix composites. Various forms and type of reinforcements, fillers and additives. Design of composites for structural, wear resistance and high temperature applications.

Unit V: Micro-electro-mechanical (MEMS) systems- Introduction, characteristics of silicon wafers and other materials for MEMS applications. Various manufacturing techniques of MEMS components Materials for high temperature applications - Ni-Cr alloys, ODS materials, Ni base and Co based super alloys, carbon-carbon composites.

Unit VI: Powder metallurgy- Introduction and feature of powder metallurgy processes. Advanced solidification techniques: directional solidification, single crystal growth and levitation melting.

Unit VII: Advanced Material processing techniques- Thermal spraying, Ion beam machining, Laser and Electron beam processing, Friction Stir Welding, Special alloys machining, Superplastic forming, Flow forming, Explosive forming, Thin films and their deposition, Diamond coating techniques-tribological applications, Diffusion bond coating of high temperature materials.

Course Outcome:

CO1: Understand the advanced materials and its manufacturing processes for engineering applications and analyze Piezoelectric materials (PZT).

CO2: Analyze the Shape memory alloys (SMA), Electro rheological (ER) and magneto-rheological (MR) materials.

CO3: Understand the Composite materials and Micro-electro-mechanical (MEMS) systems.

CO4: Understand the Powder metallurgy and Advanced Material processing techniques.

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., Pizoelectricity, George Gorden 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 Code	Course Name	L-T-P	Credits
ME 605	Introduction to Combat Systems	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Combat systems**
- **To impart fundamental and advanced knowledge of the subject**
- **To enable the students to understand various topics of the subject such as vehicle configuration,** Battle Field Environment, Threat Spectrum etc.

Course Contents

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.

Course Outcome:
CO1: Understand the basics of 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 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 systemandCombat 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.

TextBooks/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 Code	Course Name	L-T-P	Credits
ME 607	Computational Fluid Dynamics (CFD)	**3-0-1**	**4**

Course Objectives:

- **To introduce concepts of CFD**
- **To impart fundamental and advanced knowledge of the subject**
- **To enable the students to understand various topics of the subject such as** Finite Difference, Finite element and Finite Volume formulation, Numerical methods for the Navier-Stokes equation etc.

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.

Unit III: Solution algorithms for pressure-velocity coupling in steady and unsteady flows. Discretization equations for two-dimensional convection and diffusion. Unsteady heat conduction.

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

Course Outcome:

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

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 Code	Course Name	L-T-P	Credits
ME 608	**Finite Element Methods**	**3-0-1**	**4**

Course Objectives:

- **To introduce concepts of FEM**
- **To impart fundamental and advanced knowledge of the subject**
- **To enable the students to understand various topics of the subject such as** 1-D structural problems,2-D stress analysis, Scalar field problems etc.

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.

Course Outcome:
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.

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 Code	Course Name	L-T-P	Credits
ME 609	**Mechanical Vibrations**	**3-0-1**	**4**

Course Objectives:

- **To introduce concepts of Mechanical Vibrations**
- **To impart fundamental and advanced knowledge of the subject**
- **To enable the students to understand various topics of the subject such** Free and forced vibrations, Multi-degree of Freedom and Continuous Systems, Experimental methods in vibration analysis etc.

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.

Practice:

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.

Course Outcome:

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.

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 Code	Course Name	L-T-P	Credits
ME 610	**Armament and Combat Vehicles II**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Armament and Combat systems
- **To impart fundamental and advanced knowledge of the subject**
- **To enable the students to understand various topics of the subject such** Gun and Rocket, Warhead Mechanisms, Weapon Sighting system etc.

Course Contents

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.

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 actors 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.

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 Code	Course Name	L-T-P	Credits
ME 611	**Design for Manufacturability**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Manufacturing Considerations in Design
- **To impart fundamental and advanced knowledge of the subject**
- **To enable the students to understand various topics of the subject such as Engineering Design, Machining considerations** etc.

Course Contents

Unit I: Manufacturing Considerations in Design- Design for manufacture, Tolerencing 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.

Course Outcome:

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.

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, Spriinger, 1996.

Course Code	Course Name	L-T-P	Credits
ME 612	**Modeling and Simulation of Military Vehicles**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Multi Body Dynamics.
- **To impart fundamental and advanced knowledge of the subject**
- **To enable the students to understand various topics of Vehicle dynamics, Modal Analysis, Armour / Ballistics** etc.

Course Contents

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 &Applicatios, 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 Begineers, 2012, LAP Lambert Academics Publishing, ISBN 978-3846556771

Course Code	Course Name	L-T-P	Credits
ME 613	Armour Protection Systems	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Armour Protection Systems
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of Structural Design and Protection, types of threat,** Armour Testing etc.

Course Contents

Unit-I: Type of Threats: Threats to Armoured vehicles and systems. Frontal, top, side and bottom attacks. Armoureddistribution 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, AluminiumArmour, Ceramic / Composite armour, Laminated / Spaced Armour, Explosive Reactive Armour; Active Armour - Soft Kill techniques amd 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), ElectricArmour. 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.

Course Outcome:
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, electricarmour 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.

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, RZaera, Springer: Vienna, ISBN 0978-3709105221

Course Code	Course Name	L-T-P	Credits
ME 614	Unmanned Ground vehicles	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Unmanned Ground vehicles
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of Mobile UGV Kinematics,** Automatic Transmission etc.

Course Contents

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 (PrinticeHall)
2. Autonomous robots: From biological inspiration to implementation and control, By Bekey, G.A.
3. Intelligent unmanned ground vehicles- autonomous navigation research at carnegiemellon, ByHebert, 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 Code	Course Name	L-T-P	Credits
ME 615	Trials & Evaluation of Weapon Systems	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Weapon Systems
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics.**

Course Contents

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, Accelarated 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. Inbore pressure measurement. Telemetry and Data Acquisition. Post trial Analysis. Range and Accuracy Trial. Functioning Trial. Recovery trial and inspection.

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, RaminEsfandairi and Hung V Vu, Mc Graw Hill, ISBN 978-0072966619
6. Sensors: Advancements in Modelling, Design Issus, Fabrication and Practical Applications, 2008, Yueh-Min Ray Huang, Springer, ISBN 978-3540690306

Course Code	Course Name	L-T-P	Credits
ME 616	Thermal Management of Defence Equipment	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Heat-transfer**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topicsHeat-generating electronic equipment, Thermal management equipment etc.**

Course Contents

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.

Course Outcome:

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

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 Code	Course Name	L-T-P	Credits
ME 617	Kinematics and Dynamics of Machinery	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Kinematics and Dynamics of Machines**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics such as rigid bodies in plane motion, Dynamics of Reciprocating Machines, Programmable mechanisms etc.**

Course Contents

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 reactions, 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 unbalance 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 Code	Course Name	L-T-P	Credits
ME 618	Composite Structures	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Composite materials**
- **To impart fundamental and advanced knowledge of Micro and Macro-mechanical behaviour of lamina**
- **To enable the students to understand various topics such as Fabrication methods of composites structures, Testing and characterisation of composites etc.**

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: 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 train relation for plane stress in an orthotropic material, stress-train 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 III: 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 IV: Macro-mechanical behavior of laminates-Introduction, Classical Lamination Theory, Special Cases Of Laminate Stiffness, Theoretical Versus Measured Stiffness, Strength Of Laminates, Inter-Laminar Stress.
Unit V: Introduction to design of composites structures-Introduction to structural design, material selection, configuration selection, laminate joints design requirements and design failure criteria, optimization concepts, design analysis philosophy for composite structures.
Unit VI: Fabrication methods of composites structures-Introduction to Various Fabrication Methods, VARTM And RFI Methods, Process Parameters In VARTM Method, Permeability Measurements, VARTM Process Model, Process Parameters of RFI Method Film Casting And Characteristics, Concepts Of VARTM and RFI Process Optimization.
Unit VII: Testing and characterisation of composites-Lamina strength characterization, tensile testing, compression testing, in-plane shear testing, short beam test, double cantilever beam test. Physical properties characteristion void content evaluation, fibre Volume Fraction Evaluation, DMA, DSC FOR Tg, Wet Properties of Lamina, NDE Methods, Ultrasonic A-scan and CT-Scan Methods ForChracteristion Of Composites.

Course Outcome:
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

Text books:

1. Mechanics of composite materials, by Robert. M. Jones, second sedition, 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 Code	Course Name	L-T-P	Credits
ME 619	Tribology for Design	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Tribology for Design**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics such as Friction and Wear, Lubrication of Bearings, Hydrostatic and Squeeze Film Lubrication etc.**

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, FrictionMeasurement, 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.

Unit VIII: Tribological Aspects of Rolling Motion-The mechanics of tyre-road interactions, Road grip and rolling resistance, Tribological aspects of wheel on rail contact. Finite Bearings-Hydrostatic bearings, Hydrodynamic bearings, Thrust oil bearings, Porous Bearings, Foil bearings, Heat in bearings.

Practice:

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

Course Outcome:

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

Text Books/References:

1. A. Harnoy, Bearing Design in Machinery, Marcel Dekker Inc, NewYork, 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 Code	Course Name	L-T-P	Credits
ME 620	High Energy Material Technology	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of High Energy Material Technology**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics such as Solid Rocket Propellants, Gun Propellants, High Explosives etc.**

Course Contents

Unit I: High Energy Materials: An overview, Current trends and Furture 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 prolellants (DBP) – Extruded, Fuel Rich Propellants (FRP), NEPE Propellants, Insulatior-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), Expliosive Reactive Armour, Fuel – Air explosive, Thermobaric explosives compositon, Measurement and instrumentation.

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

DETINICS, PBX & Insensitive Explosives.

Course Code	Course Name	L-T-P	Credits
ME 621	Dynamics & Armament Mechanisms	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Dynamics & Armament Mechanisms**
- **To impart fundamental and advanced knowledge of subject.**

- **To enable the students to understand various topics such as Mechanisms, Mechanisms of large Calibre Weapons, Fuze Mechanisms etc.**

Course Contents

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 Code	Course Name	L-T-P	Credits
ME 622	Ballistics of Bombs & Projectiles	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Ballistics of Bombs & Projectiles**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics such as Internal Ballistics, External Ballistics of Rockets, Bomb Ballistics etc.**

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 Code	Course Name	L-T-P	Credits
ME 623	Design of Ordnance, Basic and Super Structure	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Ordnance, Basic and Super Structure**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics such as Gun Barrel and Tube Launcher, Breech Mechanism etc.**

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 Code	Course Name	L-T-P	Credits
ME 624	Small Arms and Cannons	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Small Arms and Cannons**
- **To impart fundamental and advanced knowledge of subject.**

- **To enable the students to understand various topics such as** Recoil and Gas Operation systems, Trigger and Firing Systems **etc.**

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 ofBlowback, 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 Code	Course Name	L-T-P	Credits
ME 625	Combat Vehicle Technology	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Combat Vehicle Technology**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics such as AFV Characteristics ,Firepower, Critical Dimensions and Design etc.**

Course Contents

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 : Steerabilty 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 0978-0710629609
6. Dynamic Behaviour of Materials, 1st edition, Marc Andrew Meyers, Wiley-Interscience, ISBN 0978-0471582625
7. Projectile Impact: Modelling Techniques and Assessment of Target Material Performance, 2014, S Syngellakis, Wit Pr, ISBN 0978-1845648794
8. Protection Levels for Occupants of Logistic and Light Armored Vehicles,
   NATOSTANAG 4569

Course Code	Course Name	L-T-P	Credits
ME 626	Vehicle Dynamics	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Vehicle Dynamics**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics such asVehicle Ride, Wheeled Vehicle,Tracked Vehicle Handling etc.**

Course Contents

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: Terramechanics : 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. Auotmotive Handbook, 8th edition, Robert Bosch GmbH, Wiley Blackweel, 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.Dixion, SAE International, ISBN 978-0768018431
7. Car Suspenion and Handling, 4th edition, Goeffrey 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 NikolaevichBelousov and Sergey.D.Popov, SAE International, ISBN 978-0768077230

Course Code	Course Name	L-T-P	Credits
ME 627	Fatigue, Fracture and Failure Analysis	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Fatigue of Structures**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics such asPhysical Aspects of Fatigue,Fracture Mechanics, Fatigue Design and Testingetc.**

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.

Course Outcome:
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.

TextBooks/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 Code	Course Name	L-T-P	Credits
ME 628	Design of Hydraulic and Pneumatic Systems	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Hydraulic and Pneumatic Systems**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics such asDesign of Hydraulic Circuits, Pneumatic Circuitsetc.**

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 Code	Course Name	L-T-P	Credits
ME 629	Design of Experiments	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Design of Experiments**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Unit I: Overview and Basic Principles, Simple Designs and Analysis of Variance,

Unit II: Block Designs, Latin Squares and Related Designs, Full Factorial Designs, 2-level Full Factorial and Fractional Factorial Designs.

Unit III: Response surface methods and designs, Designs with Random Factors, Nested Designs, and split-plot Designs.

Text Books/References:

1. Clewer, A.G. and D.H. Scarisbrick. 2001. Practical Statistics and Experimental Design for Plant and Crop Science. John Wiley and Sons, LTD. New York Morris, T.R. 1999.
2. Experimental Design and Analysis in Animal Sciences. CABI Publishing, New York

Course Code	Course Name	L-T-P	Credits
ME 630	Design of Machinery	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of Design of Machinery**
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects such as Kinematics of mechanisms/machineries, Dynamics of mechanisms/machineries etc.**

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 – Involutes 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

Course Outcome:
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.

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 Dukkipati.R.V. Mechanisms and Machine Theory, Wiley-Eastern Ltd., New Delhi, 1992.

Course Code	Course Name	L-T-P	Credits
ME 631	Product Design and Development	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Product Design and Development
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects such as Theory of inventive problem solving, Design Thinking, Additive Manufacturing etc.**

Course Contents

Unit I: Product Design
- Prospect identification
- Customer Requirements/Customer Experience

o Generation-Development-Evaluation” of multiple concepts enabling definition of Product Architecture, form, function, styling, design language, size, variability, durability, reliability, performance & Ergonomics.
o CAD softwares& Digital product development Simulations tools
o Environmental sustainability/”cradle to cradle” approach
o Ergonomics
o Creation of Bill of material (BoM)
o DFM/DFA overview
o Testing & Validation
o Managing Intellectual Property Rights (IPR)

Unit II: Product Development
o Phases of Product Development: Product strategy definition, Product Planning, Product Design, digital & physical testing and validation, Tooling/ Fixture development, Pre-Production, Manufacturing & Sales
o Product strategy definition
o Product Planning
o Competition assessment
o Technical and commercial evaluation of concepts
o Digital & physical testing and validation
o Production readiness and Introduction to Market
o Detailed design consideration of cast, forged, machined, sheet metal, rubber parts etc.
o DFX: Design for Assembly (DFA), Design for Manufacturing (DFM), Design for Inspection (DFI), Design for Variability (DFV) & Design for Cost(DFC)
o Product costing
o Scenarios of Product design Economics

Unit III: Theory of inventive problem solving (TRIZ)
o Fundamentals, methods and techniques, General theory of innovation and TRIZ, Application of value engineering in Product design and development, Model based technology for generating innovative ideas.

Unit VI :Design Thinking
o 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: Manufacturing Considerations in Design
o Design for manufacture
o GD&T - Geometric Dimensioning & Tolerances including location, Runout. Profile, Orientation & form.
o Processing techniques and limitations for metals, polymers and ceramics. Influence of materials in processing and tooling on the design of components.
o Finishing, surface coatings and surface modifications of materials.

o Design for accuracy, locating pins and registers, machining in assembly, adjustment. Backlash and clearance adjustment.

Unit VI: 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"

Course Outcome:

CO1: Understand the Product Design, Phases of Product Development, Design for Assembly (DFA), Design for Manufacturing (DFM).

CO2: Analyze the Theory of inventive problem solving (TRIZ) and Emphasis on the powerful process of innovative problem solving.

CO3: Understand the Manufacturing Considerations in Design systems.

CO4: Understand the Additive Manufacturing (AM) and Rapid Prototyping.

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, Spriinger, 1996.

8 Ian Gibson, David W. Rosen and Brent Stucker, Additive manufacturing technologies: rapid prototyping to direct digital manufacturing, Springer, 2010.

Course Code	Course Name	L-T-P	Credits
ME 632	Design Optimization	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Design Optimization
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Unit I: Introduction-Design Characteristics of Mechanical Elements - Adequate and Optimum design - Principles of optimization - Conventional Vs Optimal design process - Design variables -

Formulation of objective function – Design constraints - Variable bounds - Classification of Engineering optimization problem.

Unit II: Single Variable Optimization Techniques-Optimality Criteria - Bracketing Methods - Exhaustive search method - Bounding phase method – Region Elimination Methods - Interval halving method - Fibonacci search method - Golden section search method - Gradient based Methods - Newton - Raphson method - Bisection method - Secant method - Cubic search method.

Unit III: Multi Variable and Constrained Optimization Techniques-Optimality criteria - Direct search Method - Simplex search methods - Hooke-Jeeve's pattern search method - Powell's conjugate direction method - Gradient based method - Cauchy's method - Newton's method - Conjugate gradient method. Kuhn - Tucker conditions - Penalty Function - Concept of Lagrangian multiplier - Complex search method - Random search method

Unit IV: Intelligent Optimization Techniques-Introduction to Intelligent Optimization - Soft Computing - Working principles of Genetic Algorithm Types of reproduction operators, crossover & mutation, - Simulated Annealing Algorithm - Particle Swarm Optimization (PSO) - Graph Grammer Approach - Example Problems

Unit V: Engineering Applications-Structural applications - Design of simple truss members. Design applications - Optimum design of simple axial, transverse loaded members - Optimum design of shafts - Optimum design of springs. Dynamic applications - Optimum design of single, two degree of freedom systems and gear vibration absorbers. Mechanisms applications - Optimum design of simple linkage mechanisms

Text Books/References:

1. Jasbir S Arora, *Introduction to Optimum design*, Mechrawhill International, 2011.
2. S. S.Rao, *Engineering Optimisation: Theory and Practice*, Wiley- Interscience, 2008.
3. K. Deb, *Optimization for Engineering design algorithms and Examples,* Prentice Hall of India Pvt. 2005.
4. C.J. Ray, *Optimum Design of Mechanical Elements,* Wiley, John & Sons, 2007.
5. R.Saravanan, *Manufacturing optimization through intelligent techniques,* Taylor & Francis Publications.

Course Code	Course Name	L-T-P	Credits
ME 633	Mechanical Behavior of Materials	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Mechanical Behavior of Materials
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Course Contents

Unit I: Introduction to deformation behaviour- Concept of stresses and strains, engineering stresses and strains, Different types of loading and temperature encountered in applications, Tensile

Test - stress – strain response for metal, ceramic and polymer, elastic region, yield point, plastic deformation, necking and fracture, Bonding and Material Behaviour, theoretical estimates of yield strength in metals and ceramics.

Unit II: Elasticity Theory- The State of Stress and strain, stress and strain tensor, tensor transformation, principal stress and strain, elastic stress-strain relation, anisotropy, elastic behaviour of metals, ceramics and polymers.

Unit III: Yielding and Plastic Deformation- Hydrostatic and Deviatoric stress, Octahedral stress, yield criteria and yield surface, texture and distortion of yield surface, Limitation of engineering strain at large deformation, true stress and true strain, effective stress, effective strain, flow rules, strain hardening, Ramberg- Osgood equation, stress - strain relation in plasticity, plastic deformation of metals and polymers.

Unit IV: Microscopic view of plastic deformation- crystals and defects, classification of defects, thermodynamics of defects, geometry of dislocations, slip and glide, dislocation generation - Frank Read and grain boundary sources, stress and strain field around dislocations, force on dislocation - self-stress, dislocation interactions, partial dislocations, twinning, dislocation
movement and strain rate, deformation behavior of single crystal, critical resolved shear stress (CRSS), deformation of poly-crystals - Hall-Petch and other hardening mechanisms, grain size effect - source limited plasticity, Hall- Petch breakdown, dislocations in ceramics and glasses.

Unit V: Fracture- Fracture in ceramics, polymers and metals, different types of fractures in metals, fracture mechanics – Linear fracture mechanics -KIC, elasto-plastic fracture mechanics - JIC, Measurement and ASTM standards, Design based on fracture mechanics, effect of environment, effect of microstructure on KIC and JIC, application of fracture mechanics in the design of metals, ceramics and polymers.

Unit VI: Deformation under cyclic load- Fatigue-S-N curves, Low and high cycle fatigue, Life cycle prediction, Fatigue in metals, ceramics and polymers.

Unit VII: Deformation at High temperature- Time dependent deformation - creep, different stages of creep, creep and stress rupture, creep mechanisms and creep mechanism maps, creep under multi-axial loading, microstructural aspects of creep and design of creep resistant alloys, high temperature deformation of ceramics and polymers.

Text Books/References:

1. J. Roesler, H. Harders,and M. Baeker,"Mechanical Behaviour of Engineering Materials: Metals, Ceramics, Polymers, and Composites", Springer- Verlag, 2007.
2. W.K. Liu, E.G. Karpov, H.S. Park, "Nano Mechanics and Materials", John Wiley and Sons Pvt. Ltd, 2006.
3. Thomas H. Courtney, "Mechanical Behavior of Materials", McGraw-Hill, 1990.

Course Code	Course Name	L-T-P	Credits
ME 634	Experimental Stress Analysis	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Experimental Stress Analysis

- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

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 N DT, 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. Hetyenyi, 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 Code	Course Name	L-T-P	Credits
ME 635	CAD	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** CAD.
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Course Contents

Unit I: CAD Hardware and Software, Types of systems and system considerations, input and output devices, hardware integration and networking, hardware trends, Software modules,

Unit II: Computer Communications, Principle of networking, classification networks, network wring, methods, transmission media and interfaces, network operating systems,
Unit III: Computer Graphics Introduction, transformation of geometric models: translation, scaling, reflection, rotation, homogeneous representation, concatenated transformations; mappings of geometric models, translational mapping rotational mapping, general mapping, mappings as changes of coordinate system; inverse transformations and mapping;
Unit IV : Projections of geometric models, orthographic projections, Geometric Modeling, curve representation: Parametric representation of analytic curves, parametric representation of synthetic curves, curve manipulations. Surface representation,
Unit V : Fundamentals of solid modeling, boundary representation (B-rep), Constructive Solid Geometry (CSF), sweep representation, Analytic Solid Modeling (ASM), other representations; solid manipulations, solid modeling based applications: mass properties calculations, mechanical tolerancing, etc.
Unit VI: Finite Element Modeling and Analysis, Finite Element Analysis, finite element modeling, mesh generation mesh requirements, semiautomatic methods, fully automatic methods, design and engineering applications, System Simulation, Need of simulation, areas of applications, when simulation is appropriate tool / not appropriate, concept of a system, components of a system, discrete and continuous systems, model of a system, types of models, types of simulation approaches

Text Books/References:
1. IbrahbimZeid, “CAD / CAM Theory and Practice”.
2. Jim Browne, “Computer Aided Engineering and Design”.
3. P. Radhakrishnan / V. Raju / S. Subramanyam, “CAD / CAM / CIM”.
4. P.N. Rao, “CAD / CAM principles and applications”, Tata Mcraw-Hill, 2002.
5. Rogers / Adams, “Mathematical Elements for Computer Graphics”.
6. Rooney and Steadman, “Principles of Computer Aided Design”, Aug. 1993.

Course Code	Course Name	L-T-P	Credits
ME 636	**MEMS - Design, Fabrication, and Characterization**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** MEMS
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

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 nanopositioning 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 Code	Course Name	L-T-P	Credits
ME 637	**Design of Pressure Vessels**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Pressure Vessels
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

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 III: 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. Buterworths 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 Code	Course Name	L-T-P	Credits
ME 641	**Warship Transmission and Tribology**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Warship Transmission and Tribology
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects, such as Gear classification, analysis and design; NES design requirements; Bearing classification, analysis and design; basic concepts of tribology and lubrication for ship transmission drives**

Course Contents

Unit I: Warship Transmission Design- Specifications, design and design checks of Marine Gearboxes (Spur and helical gears, Gear Tooth loads, Bearing loads, Reaction torque, Causes and classification of gear failures, gear noise and stress analysis).

Unit II: Shafting- Shafting (NES requirements, torsional and bending strength calculations), Shaft-line Bearings (NES requirements, types, numbers and load distribution), Clutches and Couplings

Unit III: Tribology- Theory of wear, its types and reduction, Theory of hydrodynamic lubrication, properties of marine lubricants.

Unit IV: Bearings- Classification, selection and performance. Theories of design of Journal Bearings and Rolling element bearings with performance and life estimation

Unit V: Modern Lubrication, Surface treatment.

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 system.

CO3: Students will be able to **analyze & apply** different types of hydrodynamic bearings starting from basic governing equations and estimate performance of rolling contact bearings

CO4: Student will **understand** basics of tribology, lubricants used in marine engines & modern lubrication

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

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 Code	Course Name	L-T-P	Credits
ME 642	**Automatic Control Systems**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Automatic Control Systems
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Course Contents

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.

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

Texts Books:

1. Measurement System, Application & Design, 4^{th}Ed, E O Doebelin, Mc Graw Hill, 2003.
2. Modern Control Engineering, 4th Ed, Katushiko Ogata, Pearson, UK, 2001.
3. Modern Control Engineering, 4th Ed, Katushiko Ogata, Pearson, UK, 2001.

Course Code	Course Name	L-T-P	Credits
ME 643	**Ship Dynamics and Marine Systems**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Ship Dynamics and Marine Systems
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects, such as ship categorization, geometry, stability, power calculation and propeller design concepts, ship and different ship systems design requirements, NBCD and sea trial requirements and procedures**

Course Contents

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.
Unit V: Trials: Sea trials, their requirements and procedures.

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 & V	CO4

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 Code	Course Name	L-T-P	Credits
ME 644	**Marine Diesel & Steam Engines**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Marine Diesel & Steam Engines
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects, such as basic combustion concepts, Marine diesel engine characteristics & rating, engine to**

propeller matching principles, noise and emission regulation and control, boiler and steam turbine concepts, steam turbine design requirements.

Course Contents

Unit I: Basic Concepts- Reactive Thermodynamics, complete and incomplete combustion, volumetric efficiency. Design Requirements, Materials, Types of Supercharging
Unit II: 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 III: Noise and Emission Reduction in marine engines- Regulations, Constituents, Control Mechanisms for reduction of noise and exhaust emissions from marine diesel engines.
Unit IV: Boiler Design- Boiling process, heat transfer and fluid flow dynamics, boiler design considerations, procedure. Steam cycles analysis: Steam turbine thermodynamics, Simple Rankine cycle, Power output and efficiency calculations, measures to improve cycle performance parameters.
Unit V: Steam turbines-Impulse and reaction turbines, multistaging in turbines, compounding of turbines, design and part load performances, turbine losses. Steam turbine design procedure.

Course Outcome:
CO1: Students will be able to **analyze**&**apply** basic reactive thermodynamics and **explain** requirements of marine diesel engine design
CO2: Students will be able to **analyze, apply and explain** Marine Diesel Engine rating, selection & engine-propeller matching
CO3: Student will be able **analyze and explain**regulations & control Mechanisms for noise and emissions control from marine diesel engines
CO4: Students will be able to **understand, analyze & apply** basic working characteristics, performance & basic design considerations of boilers & steam turbines using thermodynamic charts/relations

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

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. Steam Turbines: Theory and Design, Shlyakhin P, Foreign Languages Publishing House, Moscow, 1995.

Course Code	Course Name	L-T-P	Credits
ME 645	**Marine Gas Turbines**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Marine Gas Turbines
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects, such as basic Gas dynamics concepts; Gas turbine (GT) types, applications and performance analysis; compressor-turbine matching and propeller matching principles, compressor/turbine design and performance, Mechanical design concepts and materials and design requirements of Marine GT's.**
-

Course Contents

Unit I: Gas Turbine theory and Performance: Gas dynamics, thermodynamic and fluid mechanics concepts, Gas Turbine Types and application, Cycle Analysis & Performance. Design & off- design point performance, Transient performance of single shaft, two shaft engine with FPT. Gas Turbine Simulation. Compressor turbine Matching. Propeller matching, displacing equilibrium running line.

Unit II: Turbo Machinery Aerodynamics Design: Compressor design and Performance - Pressure losses separation & friction losses, Definition delta upon D, De Hallers no. Stage loading and flow parameters, degree of reaction, stall, Use of IGVs & VGVs, multi-spooling, variable temp rise distribution. Compressor design co-relations & example.

Unit III: Mechanical Design and Performance of Turbine and Compressors: Blade shapes, methods of design. Velocity triangles, reaction, stage loading, flow coefficient. Design for maximum power. Stage efficiency, over-tip leakage. Design correlations & example. Centrifugal, Gas, Inertia Loads acting on turbo-machinery,

Unit IV: Creep design, Fatigue design, Requirements of naval application. Marine GT Combustors Design.

Unit V: Design & Materials for Marine GTs. Requirements, properties, Super-alloys, Manufacturing, Marine coatings, Types & Process. Marine GT Systems Design requirements & Integration with ships systems.

Course Outcome:

CO1: Students will be able to **analyze, apply & explain** basic working of marine gas turbines in terms of its thermodynamic and mechanical behaviour

CO2: Students will be able to **analyze, apply & explain** aerodynamic & mechanical design & performance characteristics of gas turbines and compressors

CO3: Students will be able to **analyze, interpret & explain** mechanical design requirements of Marine gas turbine components & recommend suitable materials for its manufacturing

Syllabus Details	Outcome
Unit I	CO1
Unit II & III	CO2

Unit IV & V	CO3

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, 6^{th} Ed, Elsevier, 2010.
3. Gas Turbine 2^{nd} Ed, V Ganeshan, Tata McGraaw 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 Code	Course Name	L-T-P	Credits
ME 646	**Nuclear Reactor Engineering**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Nuclear Reactor Engineering
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Course Contents

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.

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

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 Code	Course Name	L-T-P	Credits
ME 654	**Convective Heat & Mass Transfer**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Convective Heat & Mass Transfer
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Course Contents

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, Introduction to Mixed convection: Thermal expansion number, Archimedes number, Froude number

Unit V: Condensation and Boiling
Introduction, film condensation on a vertical plate, average heat transfer coefficient, Laminar film condensation inside and outside of horizontal tubes, Introduction to boiling, modes of boiling

Unit VI: Mass Transfer

Introduction, Conservation of species for a control volume, mass diffusion equation, concentration boundary layer, Schmidt number, Sherwood number, Lewis number, Heat and mass transfer analogy, Evaporative cooling

Practice: Solve thermal boundary layer over flat plate using Matlab/C/python code

Course Outcome:
CO1: Students will be able to **explain, analyze & apply** basic conduction & 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 radiation & mass transfer. **Understand** non-dimensional parameters affecting convective mass transfer in combined heat & mass transfer processes like boiling & condensation

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

Text Books:
I. Introduction to Convective Heat Transfer Analysis by Patrick H. Oosthuizen and David Layor (McGrow-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 Sctllichting (McGraw-Hill)
III. Heat and Mass transfer by Eckert ERG and Drake RM (Translated by J P Gross, McGrow-Hill)
IV. Convective Heat Transfer: Solved Problems by Michel Favre-Marinet and SedatTardu (Wiley)

Course Code	Course Name	L-T-P	Credits
ME 655	**Performance Testing and Instrumentation**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Performance Testing and Instrumentation
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Course Contents

Unit I: Performance testing of Machinery Sea Water Cooling, Lube Oil Fill/Transfer/Purification Systems, - Main Propulsion Lube Oil System, Starting Air Compressors and System, Ship Service and Control Air Equipment, Segregated Ballast System, Steam and Condensate System, Fuel Oil Service System, Fuel Oil Quick Closing Valves, High Temperature/Low Temperature Fresh Water Cooling Systems, Stern Tube Lube Oil System,

Unit II: Performance testing of Ship Service Generator Operational Tests, Emergency Diesel Generator , Batteries and Chargers, Lighting System Operation, Navigation and Signal Lights, Radio Communication Equipment, Ships Whistles, Tank Level Indicators, Auxiliary Boiler and Services, Fire and Foam System, Machinery Bilge and Oily Waste Transfer System

Unit III: Fundamental & Importance of Instrumentation, types of instruments, selection of instruments, performance of instruments, error in measurement, calibration & standard, Calibration of Instruments: Methods & analysis, Introduction to Transducer & types, Process Instrumentation, recording instruments, indicating & recording Instruments.

Unit IV: Measurements of temperature, pressure, relative humidity, moisture content & velocity & flow.

Text books/Reference:

1. Experimental Methods, J.P. Holman McGraw Hill International, Auckland
2. Engineering Metrology, R KJain, Khanna Publishers, Delhi
3. Mechanical Measurements, Thomos G. Beckwith and I.ewis Back N. Adison Wesely Longman, Harlow
4. Industrial lnstrurnentation, John Wiley Eastern Ltd, New Delhi

Course Code	Course Name	L-T-P	Credits
ME 657	***Marine Hydrodynamics***	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Marine Hydrodynamics
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Course Contents

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; Blausius 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.

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; Blausius 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

Text Books:

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 Code	Course Name	L-T-P	Credits
ME 658	**Additive Manufacturing**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Additive Manufacturing
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Course Contents

Unit I: Review of solid modeling techniques with comparison. Product development. Simultaneous Engineering and Additive Manufacturing(AM). Basic Principle of AM processes.

Unit II: Support structure in Additive Manufacturing. Containment and critical applications. Generation of the physical layer model. Classification of AM Processes.

Unit III: Virtual Prototyping. Tessellation (STL format) and tessellation algorithms. Defects in STL files and repairing algorithms. Slicing and various slicing procedures.

Unit IV: Accuracy and Surface quality in Additive Manufacturing. Effect of part deposition orientation on accuracy, surface finish, build time, support structure, cost etc. Various Rapid tooling techniques. Introduction to Reverse Engineering. Reverse engineering and Additive Manufacturing.

Text /References*:*

1. Ian Gibson, David W. Rosen and Brent Stucker, Additive manufacturing technologies: rapid prototyping to direct digital manufacturing, Springer, 2010.

2. C.K. Chua, K.F. Leong and C.S. Lim, Rapid prototyping: Principles and applications, 3 rd Edition, World Scientific, 2010

3. Andreas Gebhardt, Understanding additive manufacturing: rapid prototyping, rapid tooling, rapid manufacturing, Hanser Publishers, 2011.

4. L. Lu, J. Fuh and Y. S. Wong, Laser-induced materials and processes for rapid prototyping, Kluwer Academic Press, 2001.

5. Zhiqiang Fan and Frank Liou, Numerical modeling of the additive manufacturing (AM) processes of titanium alloy, lnTech, 2012.

Course Code	Course Name	L-T-P	Credits
ME 659	**Rapid Prototyping**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Rapid Prototyping
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Course Contents

Unit I: Introduction- History, Development of RP systems, Applications in Product Development, Reverse Engineering, Rapid Tooling, Rapid Manufacturing- Principle, Fundamental, File format, Other translators, medical applications of RP, On demand manufacturing, Direct material deposition, Shape Deposition Manufacturing.

Unit II: Liquid Based and Solid Based Rapid Prototyping Systems: Classification, Liquid based system, Stereolithography Apparatus (SLA), details of SL process, products, Advantages, Limitations, Applications and Uses. Solid based system – Fused Deposition Modeling, principle, process, products, advantages, applications and uses – Laminated Object Manufacturing.

Unit III: Powder Based Rapid Prototyping Systems- Selective Laser Sintering – principles of SLS process, principle of sinter bonding process, Laser sintering materials, products, advantages, limitations, applications and uses. Three Dimensional Printing – process, major applications, research and development. Direct shell production casting – key strengths, process, applications and uses, case studies, research and development. Laser Sintering System, e-manufacturing using Laser sintering, customized plastic parts, customized metal parts, e-manufacturing – Laser Engineered Net Shaping (LENS).

Text Books

- Rafiq I. Noorani, Rapid Prototyping, "Principles and Applications", Wiley & Sons, 2006.
- Chua C.K, Leong K.F and Lim C.S, "Rapid Prototyping: Principles and Applications", Second Edition, World Scientific, 2003.

References:

- N.Hopkinson, R.J.M, Hauge, P M, Dickens, "Rapid Manufacturing – An Industrial revolution for the digital age", Wiley, 2006
- Ian Gibson, "Advanced Manufacturing Technology for Medical applications: Reverse Engineering, Software conversion and Rapid Prototying", Wiley, 2006
- Paul F.Jacobs, "Rapid Prototyping and Manufacturing : Fundamentals of Stereolithography", McGraw Hill 1993.
- Pham. D.T., and Dimov. S.S., "Rapid Manufacturing", Springer Verlog 2001.

Course Code	Course Name	L-T-P	Credits
ME 660	**Heat Exchanger Design**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Heat Exchanger Design
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Course Contents

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

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.

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 SadikKakaç, Hongtan Liu, AnchasaPramuanjaroenkij (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. KaysandA.L. London, (Krieger Publishing Company)
3. Fundamentals of heat transfer - Frank P. Incropera, David P. DeWitt

Course Code	Course Name	L-T-P	Credits
ME 661	**Computational Fluid-Structure Interaction and its Applications**	**3-1-0**	**4**

Course Objectives:

- **To introduce concepts of** Computational Fluid-Structure Interaction
- **To impart fundamental and advanced knowledge of subject.**
- **To enable the students to understand various topics of the subjects.**

Course Contents

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-dimensionalconduction 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, Expilict 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

Course Outcome:

CO1: Understand the real-life problems of Fluid-Structure Interactions (FSI) and fundamental of governing equations and boundary conditions. LearnFundamentals 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.

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'hamedSouli, ISBN-13: 9781118618684, Wiley
5. ANSYS AUTODYN User’s Manual, ANSYS Inc.

Course Name- M. Tech. Dissertation Phase– I
Course Code- ME 651

Course Name- M. Tech. Dissertation Phase– II
Course Code- ME 652

AUDIT 1 and 2: DISASTER MANAGEMENT

Course objectives:

Students will be able to:

1. learn to demonstrate a critical understanding of key concepts in disaster risk reduction and humanitarian response.
2. critically evaluate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
3. develop an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.
4. critically understand the strengths and weaknesses of disaster management approaches, planning and programming in different countries, particularly their home country or the countries they work in

Syllabus

Units	CONTENTS	Hours
1	**Introduction** Disaster: Definition, Factors And Significance; Difference Between Hazard And Disaster; Natural And Manmade Disasters: Difference, Nature, Types And Magnitude.	**4**
2	**Repercussions Of Disasters And Hazards**: Economic Damage, Loss Of Human And Animal Life, Destruction Of Ecosystem. Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts And Famines, Landslides And Avalanches, Man-made disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil Slicks And Spills, Outbreaks Of Disease And Epidemics, War And Conflicts.	**4**
3	**Disaster Prone Areas In India** Study Of Seismic Zones; Areas Prone To Floods And Droughts, Landslides And Avalanches; Areas Prone To Cyclonic And Coastal Hazards With Special Reference To Tsunami; Post-Disaster Diseases And Epidemics	**4**
4	**Disaster Preparedness And Management** Preparedness: Monitoring Of Phenomena Triggering A Disaster Or Hazard; Evaluation Of Risk: Application Of Remote Sensing, Data From Meteorological And Other Agencies, Media Reports: Governmental And Community Preparedness.	**4**
5	**Risk Assessment** Disaster Risk: Concept And Elements, Disaster Risk Reduction, Global And National Disaster Risk Situation. Techniques Of Risk Assessment, Global Co-Operation In Risk Assessment And Warning, People's Participation In Risk Assessment. Strategies for Survival.	**4**
6	**Disaster Mitigation** Meaning, Concept And Strategies Of Disaster Mitigation, Emerging Trends In Mitigation. Structural Mitigation And Non-Structural Mitigation, Programs Of Disaster Mitigation In India.	**4**

Suggested Studies:

1. R. Nishith, Singh AK, "Disaster Management in India: Perspectives, issues and strategies "'New
Royal book Company.
2. Sahni, PardeepEt.Al. (Eds.)," Disaster Mitigation Experiences And Reflections", Prentice Hall Of
India, New Delhi.
3. Goel S. L., Disaster Administration And Management Text And Case Studies",Deep&Deep Publication Pvt. Ltd., New Delhi.

AUDIT 1 and 2: SANSKRIT FOR TECHNICAL KNOWLEDGE

Course Objectives

1. To get a working knowledge in illustrious Sanskrit, the scientific language in the world
2. Learning of Sanskrit to improve brain functioning
3. Learning of Sanskrit to develop the logic in mathematics, science & other subjects

4. enhancing the memory power
5. The engineering scholars equipped with Sanskrit will be able to explore the
6. huge knowledge from ancient literature

Syllabus

Units	CONTENTS	Hours
1	Alphabets in Sanskrit, Past/Present/Future Tense, Simple Sentences	**8**
2	Order Introduction of roots Technical information about Sanskrit Literature	**8**
3	Technical concepts of Engineering-Electrical, Mechanical, Architecture, Mathematics	**8**

Suggested reading

1. "Abhyaspustakam" – Dr.Vishwas, Samskrita-Bharti Publication, New Delhi
2. "Teach Yourself Sanskrit" Prathama Deeksha-VempatiKutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication
3. "India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., New Delhi.

Course Output

Students will be able to
1. Understanding basic Sanskrit language
2. Ancient Sanskrit literature about science & technology can be understood
3. Being a logical language will help to develop logic in students

AUDIT 1 and 2: VALUE EDUCATION

Course Objectives

Students will be able to
1. Understand value of education and self- development
2. Imbibe good values in students
3. Let the should know about the importance of character

Syllabus

Units	CONTENTS	Hours
1	Values and self-development –Social values and individual attitudes. Work ethics, Indian vision of humanism. Moral and non- moral valuation. Standards and principles. Value judgements	**4**
2	Importance of cultivation of values. Sense of duty. Devotion, Self-reliance. Confidence, Concentration. Truthfulness, Cleanliness. Honesty, Humanity. Power of faith, National Unity. Patriotism.Love for nature,Discipline	**6**

3	□ Personality and Behavior Development - Soul and Scientific attitude. Positive Thinking. Integrity and discipline. □ Punctuality, Love and Kindness. □ Avoid fault Thinking. □ Free from anger, Dignity of labour. □ Universal brotherhood and religious tolerance. □ True friendship. □ Happiness Vs suffering, love for truth. □ Aware of self-destructive habits. □ Association and Cooperation. □ Doing best for saving nature	**6**
4	□ Character and Competence –Holy books vs Blind faith. □ Self-management and Good health. □ Science of reincarnation. □ Equality, Nonviolence,Humility, Role of Women. □ All religions and same message. □ Mind your Mind, Self-control. □ Honesty, Studying effectively	**6**

Suggested reading

1. Chakroborty, S.K. "Values and Ethics for organizations Theory and practice", Oxford University
Press, New Delhi

Course outcomes

Students will be able to
1. Knowledge of self-development
2. Learn the importance of Human values
3. Developing the overall personality

AUDIT 1 and 2: CONSTITUTION OF INDIA

Course Objectives:

Students will be able to:
1. Understand the premises informing the twin themes of liberty and freedom from a civil rights perspective.
2. To address the growth of Indian opinion regarding modern Indian intellectuals' constitutional role and entitlement to civil and economic rights as well as the emergence of nationhood in the early years of Indian nationalism.
3. To address the role of socialism in India after the commencement of the Bolshevik Revolution in 1917 and its impact on the initial drafting of the Indian Constitution.

Syllabus

Units	CONTENTS	Hours
1	□ **History of Making of the Indian Constitution:** History Drafting Committee, (Composition& Working)	**4**
2	□ **Philosophy of the Indian Constitution:**	**4**

	Preamble Salient Features	
3	**Contours of Constitutional Rights & Duties:** Fundamental Rights Right to Equality Right to Freedom Right against Exploitation Right to Freedom of Religion Cultural and Educational Rights Right to Constitutional Remedies Directive Principles of State Policy Fundamental Duties.	**4**
4	**Organs of Governance:** Parliament Composition Qualifications and Disqualifications Powers and Functions Executive President Governor Council of Ministers Judiciary, Appointment and Transfer of Judges, Qualifications Powers and Functions	**4**
5	**Local Administration:** District's Administration head: Role and Importance, Municipalities: Introduction, Mayor and role of Elected Representative, CEO of Municipal Corporation. Pachayati raj: Introduction, PRI: ZilaPachayat. Elected officials and their roles, CEO ZilaPachayat: Position and role. Block level: Organizational Hierarchy (Different departments), Village level: Role of Elected and Appointed officials, Importance of grass root democracy	**4**
6	**Election Commission:** Election Commission: Role and Functioning. Chief Election Commissioner and Election Commissioners. State Election Commission: Role and Functioning. Institute and Bodies for the welfare of SC/ST/OBC and women.	**4**

Suggested reading

1. The Constitution of India, 1950 (Bare Act), Government Publication.
2. Dr. S. N. Busi, Dr. B. R. Ambedkar framing of Indian Constitution, 1st Edition, 2015.
3. M. P. Jain, Indian Constitution Law, 7th Edn., Lexis Nexis, 2014.
4. D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015.

Course Outcomes:
Students will be able to:

1. Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics.
2. Discuss the intellectual origins of the framework of argument that informed the

conceptualization of social reforms leading to revolution in India.
3. Discuss the circumstances surrounding the foundation of the Congress Socialist Party [CSP] under the leadership of Jawaharlal Nehru and the eventual failure of the proposal of direct elections through adult suffrage in the Indian Constitution.
4. Discuss the passage of the Hindu Code Bill of 1956.

AUDIT 1 and 2: PEDAGOGY STUDIES

Course Objectives:

Students will be able to:
1. Review existing evidence on the review topic to inform programme design and policy making undertaken by the DfID, other agencies and researchers.
2. Identify critical evidence gaps to guide the development.

Syllabus

Units	CONTENTS	Hours
1	**Introduction and Methodology:** Aims and rationale, Policy background, Conceptual framework and terminology Theories of learning, Curriculum, Teacher education. Conceptual framework, Research questions. Overview of methodology and Searching.	**4**
2	Thematic overview: Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries. Curriculum, Teacher education.	**2**
3	Evidence on the effectiveness of pedagogical practices Methodology for the in depth stage: quality assessment of included studies. How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy? Theory of change. Strength and nature of the body of evidence for effective pedagogical practices. Pedagogic theory and pedagogical approaches. Teachers' attitudes and beliefs and Pedagogic strategies.	**4**
4	Professional development: alignment with classroom practices and follow-up support Peer support Support from the head teacher and the community. Curriculum and assessment Barriers to learning: limited resources and large class sizes	**4**
5	**Research gaps and future directions** Research design Contexts Pedagogy Teacher education Curriculum and assessment	**2**

	Dissemination and research impact.	

Suggested reading

1. Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, Compare, 31 (2):
245-261.
2. Agrawal M (2004) Curricular reform in schools: The importance of evaluation, Journal of Curriculum Studies, 36 (3): 361-379.
3. Akyeampong K (2003) Teacher training in Ghana - does it count? Multi-site teacher education research project (MUSTER) country report 1. London: DFID.
4. Akyeampong K, Lussier K, Pryor J, Westbrook J (2013) Improving teaching and learning of basic
maths and reading in Africa: Does teacher preparation count? International Journal Educational Development, 33 (3): 272–282.
5. Alexander RJ (2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.
6. Chavan M (2003) Read India: A mass scale, rapid, 'learning to read' campaign.
7. www.pratham.org/images/resource%20working%20paper%202.pdf.

Course Outcomes

Students will be able to understand:

1. What pedagogical practices are being used by teachers in formal and informal classrooms in developing countries?
2. What is the evidence on the effectiveness of these pedagogical practices, in what conditions, and
with what population of learners?
3. How can teacher education (curriculum and practicum) and the school curriculum and guidance materials best support effective pedagogy?

AUDIT 1 and 2: STRESS MANAGEMENT BY YOGA

Course Objectives

1. To achieve overall health of body and mind
2. To overcome stress

Syllabus

Units	CONTENTS	Hours
1	Definitions of Eight parts of yog. (Ashtanga)	**8**
2	Yam and Niyam. Do`s and Don't's in life. i) Ahinsa, satya, astheya, bramhacharya and aparigraha ii) Shaucha, santosh, tapa, swadhyay, ishwarpranidhan	**8**
3	Asan and Pranayam i) Various yog poses and their benefits for mind & body ii)Regularization of breathing techniques and its effects-Types of pranayama	**8**

Suggested reading

1. 'Yogic Asanas for Group Tarining-Part-I" :Janardan Swami Yogabhyasi Mandal, Nagpur
2. "Rajayoga or conquering the Internal Nature" by Swami Vivekananda, AdvaitaAshrama (Publication Department), Kolkata

Course Outcomes:

Students will be able to:

1. Develop healthy mind in a healthy body thus improving social health also
2. Improve efficiency

AUDIT 1 and 2: PERSONALITY DEVELOPMENT THROUGH LIFE ENLIGHTENMENT SKILLS

Course Objectives

1. To learn to achieve the highest goal happily
2. To become a person with stable mind, pleasing personality and determination
3. To awaken wisdom in students

Syllabus

Units	CONTENTS	Hours
1	Neetisatakam-Holistic development of personality Verses- 19,20,21,22 (wisdom) Verses- 29,31,32 (pride & heroism) Verses- 26,28,63,65 (virtue) Verses- 52,53,59 (dont's) Verses- 71,73,75,78 (do's)	8
2	Approach to day to day work and duties. Shrimad BhagwadGeeta : Chapter 2-Verses 41, 47,48, Chapter 3-Verses 13, 21, 27, 35, Chapter 6-Verses 5,13,17, 23, 35, Chapter 18-Verses 45, 46, 48.	8
3	Statements of basic knowledge. Shrimad BhagwadGeeta: Chapter2-Verses 56, 62, 68 Chapter 12 -Verses 13, 14, 15, 16,17, 18 Personality of Role model. Shrimad BhagwadGeeta: Chapter2-Verses 17, Chapter 3-Verses 36,37,42, Chapter 4-Verses 18, 38,39 Chapter18 – Verses 37,38,63	8

Suggested reading

1. "Srimad Bhagavad Gita" by Swami SwarupanandaAdvaita Ashram (Publication
2. Department), Kolkata
3. Bhartrihari's Three Satakam (Niti-sringar-vairagya) by P.Gopinath,
4. Rashtriya Sanskrit Sansthanam, New Delhi.

Course Outcomes

Students will be able to

1. Study of Shrimad-Bhagwad-Geeta will help the student in developing his personality and achieve the highest goal in life
2. The person who has studied Geeta will lead the nation and mankind to peace and prosperity
3. Study of Neetishatakam will help in developing versatile personality of students.

School of Robotics

Master of Technology in Automation and Robotics

Brief Description: M.Tech. in Automation and Robotics is an interdisciplinary Masters Programme offered by School of Robotics, DIAT, which is open for students of various branches of Engineering such as Mechanical Engineering, Electrical / Electronics /Tele Communication Engineering, Computer science / Information Technology Engineering, Industrial Engineering and Instrumentation Engineering. The course aims to uplift the students on knowledge, technology and applied methodologies in the field of Automation and Robotics for Industrial, medical, domestic as well as Defence sector applications.

The program is designed for eligible candidates interested in designing, developing and controlling smart/ advanced systems in the field of Robotics and Automation.

Vision:-

To be a globally recognized center of excellence in Automation and Robotics education, renowned for innovative robotic product development, advanced industrial system training, and impactful research.

Mission:-

To empower students to excel in the fields of Automation and Robotics.

Program Objectives:-

PO1- Deliver comprehensive and up-to-date curricula that cover fundamental and advanced topics in automation and robotics, supported by state-of-the-art laboratory facilities.

PO2- Promote a robust research culture that encourages the development of innovative solutions and technologies in automation and robotics, addressing real-world industrial challenges.

PO3- Equip students with the skills and knowledge to contribute meaningfully to the global automation and robotics community, driving innovation and progress in industrial technologies.

PO4- To facilitate students with hands on experience on problem solving for modern trends in real life applications.

Program Educational Outcomes-

At the end of this course student may be able to-

PEO1- Get in-depth knowledge about Robotics and Automation related technologies, systems design and product development through exposure to course work from multiple disciplines.

PEO2-Demonstrate the ability to analyze, design, and implement industrial automation systems using programmable logic controllers (PLCs), SCADA, DCS, and other relevant technologies, optimizing for efficiency and reliability in industry 4.0

PEO3- Apply fundamental and advanced principles of robotics and deploy robotic systems for a variety of industrial and societal applications.

PEO4- Conduct research and solve problems related to Automation and Robotics in the real world scenario.

Eligibility:

1. This programme is open under sponsorship category, for officers of Indian Armed forces (Army, Navy & Air force), Coast Guard, DRDO Scientists, Indian Ordnance Factories, various Defence PSU's (HAL, BEL, BDL, etc.) This programme is also open to foreign nationals from the countries approved by GOI and self sponsored eligible candidates.

2. This programme is open under scholarship category for civilian students of any relevant graduation discipline with qualified GATE score in Mechanical Engg., Computer Science and Information Technology, Electronics and Communication Engg., Electrical Engg., Aerospace Engg., Instrumentation Engg., Production and Industrial Engg., Bio-medical Engg, or relevant discipline to Automation and Robotics

Organization: M. Tech in Automation and Robotics is a four-semester master's programme. There are six compulsory courses in the first semester and two compulsory and Four elective subjects in the second semester. In each semester, three internal assessment exams as a part of continuous evaluation and an end semester examination will be conducted for each course. M. Tech dissertation first phase evaluation will be conducted at the end of third semester and at the end of the final semester, students submit their thesis and present their project work, which is evaluated by the Internal and External examiners

M. Tech Automation and Robotics

Semester I

S. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	SR 601	Industrial Automation and Industry 4.0	3	1	4
2	SR 602	Introduction to Robotics	3	1	4
3	SR603	Sensors, Actuators and Drives	3	1	4
4	SR 610	Introduction to Automatic Control system	3	1	4
5	SR 605 # Or SR 606 ##	Introduction to Mechanisms (SR 605) Or Introduction to Electronics Systems (SR 606)	3	1	4
6	AM 607	Mathematics for Engineers	3	1	4
7	PGC 601	Research Methodology and IPR	2	-	2
		Total	**20**	**06**	**26**

Note: #SR 605 for (Non – Mechanical students) & ##SR 606 for (Non- Electronics students) compulsory subject.

Semester II

S. No.	Course Code	Course	Contact hours/week		Credits
			L	T/P	
1	SR 607	Robot Dynamics and control	3	1	4
2	SR 613	AI and ML for Robotics	3	1	4
3		Departmental Elective-1	3	1	4
4		Departmental Elective-2	3	1	4
5		Elective-1	3	1	4
6		Elective-2	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	-	2
		Total	**20**	**06**	**26**

Semester- III

S. No.	Course Code	Course	Credits		Total Credits
			L	T/P	

1	SR 651	M.Tech. Dissertation Phase I	28**	14
		Total	**28**	**14**

Semester-IV

S. No.	**Course Code**	**Course**	**Credits**		**Total Credits**
			L	**T/P**	
1	SR 652	M.Tech. Dissertation Phase II	28**		14
		Total	**28**		**14**

****Contact Hours / week:-**

- 1 credit in Theory/Tutorial implies one contact hour and 1 credit in Practice/ Thesis implies two contact hours.

List of Elective subjects

Sl. No.	**Course Code**	**Course Name**
1	SR 604	Programming languages for Robots
2	SR 608	Machine vision & Image Processing for Robots
3	SR 611	Advanced control system
4	SR 612	Design aspects of Automation
5	SR 614	Swarm robotics
6	SR 615	Introduction to Humanoid Robotics
7	SR 616	Field and service Robots
8	SR 617	Aerial Robotics
9	SR 618	Robotic Path planning and control
10	--	Open elective from other department

Detailed Contents

Semester-I

Course Name-Industrial Automation and Industry 4.0

Course Code-SR 601

Course Code	Course Name	L – T – P	**Credits**
SR 601	**Industrial Automation and Industry 4.0**	3-1-0	**4**

Course Objectives:

- To impart knowledge about industrial automation PLC, SCADA, HMI and DCS system.
- To introduce the fundamental concepts in latest industrial advancements of Industry 4.0.
- Learn about product lifecycle management and various automated material handling systems and identification methods.
- To enable the students to understand and implement concepts of industry 4.0 in traditional industrial plants.

Unit I: Introduction: Automation overview, Requirement of automation systems, Architecture of Industrial Automation system. Introduction to Networking, Sensing & actuation & communication protocols- Profibus, Field bus, HART protocols, LEAN Production Systems.

Unit II: Product Lifecycle Management. Overview of material handling systems, Types of material handling equipment, Conveyor system, Automated guided vehicle system, Automated storage and retrieval systems, Overview of Automatic Identification Methods.

Unit III. Programmable logic controllers, Analog digital input and output modules, PLC programming, Ladder diagram, Sequential flow chart, PLC selection, PLC Installation, Advantage of using PLC for Industrial automation, Application of PLC to process control industries.

Unit IV: SCADA Supervisory control and data acquisition system, segments and functions of SCADA, software and hardware working, HMI-Human Machine Interface , HMI design and programming for complex technological machines, high performance HMI for I 4.0

Unit V: Distributed Control System: Overview of DCS, , DCS communication, , DCS integration with PLC and Computers, Features of DCS, Advantages of DCS, Industrial Internet Systems. Industrial IoT Layers: Sensing, Processing, Communication. Communication, Networking

Unit VI: Role of computers in measurement and control, Cyber security in Industry 4.0, Big Data Analytics and Software Defined Networks. Machine Learning and Data Science

Course Outcomes

After completing this course, the students will be able to:
CO1: Understand various software and hardware infrastructure of industrial automation and their applications in the real world.
CO2: Learn the stages of product lifecycle management and understand process operation flow.
CO3: Design the automation line for industrial process using PLC to convert traditional manufacturing system into automation industry.
CO4: Apply various techniques of computer based control to upgrade industrial automation system to industry 4.0 standard.

Text Books

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
Reference Books
1. Curtis D. Johnson, "Process Control Instrumentation Technology", 8th Edition, Pearson New International, 2013. 2. Lukas M.P, " Distributed Control Systems", Van Nostrand Reinhold Co., New York, 1986. 3. N. Viswanandham, Y. Narahari, "Performance Modeling of Automated Manufacturing Systems", 1st Edition, 2009. 4. Stuart A. Boyer, "Introduction to SCADA Systems", ISA; 4th edition, October 2009. 5. A.K. Gupta and S.K. Arora ,"Industrial Automation and Robotics: An Introduction", Mercury Learning & Information; Har/Cdr edition, February 2013. 6. Frank D. Petruzella, "Programmable Logic Controllers", 5th Edition, McGraw- Hill, New York, 2016. 7. Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat, "Industrial Internet of Things: Cyber manufacturing Systems" by Springer.

Course Name- Introduction to Robotics

Course Code-SR 602

Course Code	Course Name	L – T – P	**Credits**
SR 602	**Introduction to Robotics**	3-1-0	**4**
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: Robot classification, Types and components of Robot Anatomy, Robot terminology- Links, joints, DOF, Specification of a robot ,work volume, work space, work object , Robot geometrical configuration (PPP, RPP, RRP, RRR, etc) & Selection of Robots, Control Resolution & Spatial Resolution, Applications in industry.			

Unit II : 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 III : Robot end effectors-classification Grippers, Types of Grippers-Mechanical, finger grippers, Magnetic-vacuum/suction, Hooks, scoops and other devices, selection of grippers, gripping mechanisms, Gripper force analysis and design of Drive system for gripper, tools Characteristics and elements of End-of-Arm-Tooling.

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. Application: Two axis planar mechanism Trajectory planning.

Unit VI: Robot capabilities and applications- wheeled, tracked, legged, aerial, underwater robots, surgical robots, rehabilitation robots, humanoid robots, Nano Robots, Robotic Accidents and safety, Robot maintenance, Introduction to Robot Programming, on-line and off-line Programming, Robot Programming Languages.

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: Identify and design appropriate end effectors and grippers for specific applications
CO4: Solve inverse kinematics problems and analyze the dynamics of serial and parallel manipulators.
CO5: Plan and implement trajectory paths for robots using various motion profiles and programming techniques

Text Books

1. S.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 Pratihar, Fundamentals of Robotics, Narosa Book publisher, 2017

Course Name- Sensors, Actuators and Drives

Course Code- SR 603

Course Code	Course Name	L – T – P	**Credits**
SR 603	**Sensors, Actuators and Drives**	3-0-1	**4**

Course Objectives:
· Understand the principles, classification, and operation of various sensors and their applications. · Learn about sensors used in robotics, including proximity, ultrasonic, magnetic, and other advanced sensing technologies. · Explore the principles and types of actuators, including hydraulic, pneumatic, and electric actuators, and their applications in industry. · Study the working principles, characteristics, and control methods of AC machines like induction motors and synchronous motors. · Understand the principles, construction, and applications of special machines and electric drives, including their control and operational methods.

Unit I: Introduction to sensors & transducers - common conversion methods, Principle of operation of sensors, static characteristics, selection criteria of sensor, Encoders and its types, potentiometers, LVDT, velocity sensors Hall effect sensor signals conditioning, calibration and testing of sensor. Principle of operation of industrial sensors.

Unit II: Sensors for Robots- Proximity sensors, Ultrasonic, magnetic, light sensors, speed measurement, GPS, LIDAR, IMU motion sensor, radar, gyroscope, FT sensor, Force sensor, shape memory alloy materials, smart sensing, applications.

Unit III: Principle of operation of actuators-Hydraulic, Pneumatic, electric, other-fundamental laws, classification, Electrical actuators: working and types of DC motor, back emf, significance and applications, Speed-torque characteristics of DC motors, control methods for industrial applications.

Unit VI: AC Machines: Working principle of Induction motors, types of 1phase and 3 phase Induction Motor, slip, speed-torque characteristics, speed control calculations for industrial applications, Working principle of synchronous motors, types, concept of RMF, Speed control methods and applications.

Unit V: Special machines: Working principle, construction, speed-torque characteristics, applications, merits and demerits- Servo motors, Switched reluctance motors, BLDC motors, Stepper motor.

Unit VI: Components of electric drives, factors affecting choice of drives, fundamental torque equation, speed-torque conventions, steady state stability, multi-quadrant operation of electric drives, load torque components, load equalization, determination of motor power rating, motor duty cycles, electric braking, modes of operation, closed loop control, DC motor control, speed control, position control.

Course Outcomes

After completing this course, the students will be able to:
CO1: Classify and explain the operation and characteristics of various sensors and transducers used in industrial applications.
CO2: Describe and select appropriate sensors for robotic applications.
CO3: Explain the principles and operation of different types of actuators, including hydraulic, pneumatic, and electric, and their industrial uses.
CO4: Analyze the working principles and control methods of AC machines, including induction motors and synchronous motors, for industrial applications.
CO5: Understand the construction, operation, and control methods of special machines and electric drives, and evaluate their applications and performance in various industrial settings.

Text Books

1. Gopal K. Dubbey*, "Fundamentals of Electric Drives", (2e)*, Narosa Publishers, 2001.
2. M. H. Rashid, "Power electronics, circuits, devices and applications",Pearson publishers,2014.
3. J. B. Gupta, "Theory & performance of Electric Machines", S K Kataria & Sons,2013.

Reference Books
1. A.K.Sawhney ,"*A course in Electrical and Electronic measurements and instrumentation*" Dhanpat Rai & Co.Publication. 2. W. Shepherd, and L. N. Hully, *"Power Electronics and Motor control", (2e)*, Cambridge University, 1995. 3. R. Krishnan, *"Electric Motor Drives Modeling, Analysis, and Control", (2e)*, Prentice Hall, 2001

Course Name-Introduction to Automatic control system-

Course Code- SR 610

Course Code	Course Name	L – T – P	**Credits**
SR 610	***Automatic control system***	3-1-0	**4**
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 and types, performance specifications, Design process, Block diagrams, Laplace transform and transient analysis, closed and open loop systems. Feedback and Feed forward control system, MIMO systems, state space analysis. **Unit II:** Modeling of systems Mechanical, Electrical, hydraulic system block diagram representations, Transfer functions of motors. 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 and Steady State Error, Routh Hurvitz criterion. **Unit III**: Frequency response analysis, Frequency domain specifications, Polar Plots, Nyquist Criteria systems, stability analysis using Nyquest plots, Gain margin, Phase margin. Experimental determination of transfer function. Stability Analysis. Root Locus Technique			

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

Unit VI: Case Studies.

Course Outcomes

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

· **CO1:** Define and categorize automatic control systems, analyze performance specifications, and design systems using block diagrams.
· **CO2:** Model mechanical, electrical, and hydraulic systems with block diagrams, derive transfer functions of motors, and perform block diagram reduction techniques.
· **CO3:** Analyze time response characteristics, including transient response and time domain specifications, and evaluate stability using Routh-Hurwitz criterion.
· **CO4:** Conduct frequency response analysis, including polar plots and Nyquist criteria, assess stability using gain margin, phase margin, and Nyquist plots, and determine transfer function experimentally.
· **CO5:** Implement control actions such as discrete, proportional, integral, and differential control, understand the characteristics and limitations of comparators, actuators, amplifiers, servo motors, and control valves.

Text /Reference Books

1. Nise, N.S., Control Systems Engineering, 5th Ed., Willey, 2008.
2. Ogata, K., “ Modern Control Engineering”, 5th Ed., Prentice Hall of India, 2013.
3. Kuo, B.C., “Automatic Control System”, 5th Ed., Prentice Hall of India, 1995.
4. 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 Name- Introduction to Mechanisms (Non Mechanical)

Course Code- SR 605

Course Code	Course Name	L – T – P	**Credits**
SR 605	***Introduction to Mechanisms (Non Mechanical)***	3-1-0	**4**

Course Objectives:

· Understand the basics of mechanics and apply to simple machines such as inclined planes, screw jacks, gears, belts, pulleys to analyze them.

· Understand the basic of kinematics for constrained rigid bodies and apply to planar and spatial mechanisms.

· Apply kinematics analysis to planar mechanisms.

· Understand planar linkages, gear drives, and basic mechanisms such as straight-line mechanisms and ratchet mechanisms.

Unit I Physical Principles: Force and Torque, Motion, Newton's Law of Motion, Momentum and Conservation of Momentum, Work, Power and Energy, material properties and selection, torque calculations and gearbox transmission mathematics for application.

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

Unit III Machines and Mechanisms: Planar and Spatial Mechanisms, Kinematics and Dynamics of Mechanisms, Links, Frames and Kinematic Chains, Skeleton Outline, Pairs, Higher Pairs, Lower Pairs and Linkages, Kinematic Analysis and Synthesis.

Unit IV Kinematics: Basic Kinematics of Constrained Rigid Bodies, Degrees of Freedom of a Rigid Body, Kinematic Constraints, Constrained Rigid Bodies, Degrees of Freedom of Planar Mechanisms

Unit V Planar Linkages: Introduction, Four Link Mechanisms, Cams, Gears: Gear Classification, Gear-Tooth Action, Involute Curve, Terminology for Spur Gears, Condition for Correct Meshing, Ordinary Gear Trains, Planetary gear trains.

Unit VI Basic Mechanisms: Straight line mechanisms, Ratchet Mechanism, Overrunning Clutch, Intermittent Gearing, Geneva Wheel mechanism, Universal Joint.

Unit V: Motion estimation and tracking: Optical flow estimation, the concept of sensor fusion - Kalman filter, Localization and Mapping techniques, object tracking with Kalman filtering, feature extraction & object recognition

Unit VI: Case studies/application: Industrial application of vision controlled Robotics systems, industrial robot guidance, demonstration of applications using computer vision toolbox and image processing toolbox.

Course Outcomes

After completing this course, the students will be able to: · **CO1:** Apply physical principles of force, torque, and motion to solve problems involving energy, material properties, and torque calculations. · **CO2:** Describe and analyze the operation and efficiency of simple machines, including inclined planes, gears, and pulleys. · **CO3:** Understand and perform kinematic analysis of mechanisms, including kinematic chains and linkages. · **CO4:** Analyze the degrees of freedom and kinematic constraints of constrained rigid bodies and planar mechanisms. · **CO5:** Design and analyze planar linkages, gear trains, and various basic mechanisms, understanding their applications and functionality.
Text Books
1. Irving H. Shames& GK Mohana Rao, *Engineering Mechanics: Statics and Dynamics*, PEARSON Education, 2006 2. Shingley.J.E. *Theory of Machines and Mechanisms*, 2nd Edition, McGraw Hills Inc, 1995. 3. J.E. Shigley, *Mechanical Engineering Design*, McGraw Hill International,2001.
Reference Books
1. P. Beer& Johnson, *Vector Mechanics for Engineers: Statics and Dynamics*, Tata McGraw Hill, New Delhi,2001. 2. Thomas Bevan, *Theory of machines*

Course Name- Introduction to Electronics Systems (Non Electronics)

Course Code- SR606

Course Code	Course Name	L – T – P	**Credits**
SR 606	***Introduction to Electronics Systems (Non Electronics)***	3-1-0	**4**
Course Objectives: · Understand the operation and characteristics of various semiconductor devices and rectifier circuits, and their application in regulated power supplies. · Learn about different types of amplifiers, operational amplifiers, and oscillators, and their applications in electronic circuits. · Explore the basics of computing, including number systems, logic gates, combinational and sequential circuit design, and programmable logic devices. · Understand the principles and applications of various measurement instruments, sensors, and data converters. · Study various electronic systems, including analog and digital communication systems, embedded systems, and electric drives.			

Unit-I: REVIEW SEMICONDUCTOR DEVICES

Two terminal devices, three terminal devices: BJT, JFET, MOSFET, four terminal devices: SCR, DIAC, TRIAC, photo devices: photo diode, LED, LCD. Half wave and full wave rectifiers, filter circuits, regulated power supplies: introduction, characteristics, stabilization.

Unit-II: AMPLIFIERS AND OSCILLATORS

Transistor as an amplifier, single stage amplifier, multistage amplifier, Class A, B, and C amplifiers. Introduction to operational amplifier, specification and characteristics, application: constant gain, voltage summing, voltage buffer, instrumentation circuits, active filters. Oscillators.

Unit-III: INTRODUCTION TO COMPUTING

Number system and code conversion, logic gates, Boolean algebra, combinational circuit design, sequential circuit, flip flops, counters, shift registers, decoder, encoder, MUX, DEMUX, memories, I/O, programmable logic devices, microprocessors and microcontrollers.

Unit-IV: MEASUREMENTS AND INSTRUMENTS

Introduction, Analog to Digital converters and Digital to Analog converters, digital multimeter, frequency counters. Electronic circuits for sensors: temperature sensor, force and pressure sensor, magnetic field sensor, optical sensor, microwave sensor, acoustic sensor, and image sensor, etc.

Unit-V: COMMUNICATION AND SIGNAL PROCESSING

Analog communication system, digital communication system, wireless communication system, embedded system, real time system, VLSI, RF, Signal processing, signal conditioning.

Unit-VI: ELECTRIC DRIVES

Electric power converters: Rectifiers, choppers, inverters, cycloconverters, Power flow control switching, power electronic devices, SCR, V- I, turn on, turn off characteristics, Switching devices triggering methods, PWM methods. Power converters static Kramer drive, static Scherbius drive, stepper motor drives, BLDC drivers, PMAC drivers, switched reluctance motors drives.

Course Outcomes

After completing this course, the students will be able to: · **CO1:** Explain the principles, operation, and characteristics of semiconductor devices, rectifier circuits, and regulated power supplies. · **CO2:** Analyze and design different types of amplifiers, operational amplifiers, and oscillators for various applications. · **CO3:** Understand and design basic computing circuits, including logic gates, flip-flops, counters, and memory devices. · **CO4:** Utilize measurement instruments and sensors, and understand the conversion processes between analog and digital signals. · **CO5:** Describe and analyze various electronic systems, including communication systems, embedded systems, and electric drives.
Text Books
1. Thomas L. Floyd, Electronic Devices, Pearson Education, 9th Edition, 2012. 2. Gopal K. Dubbey, *"Fundamentals of Electric Drives", (2e)*, Narosa Publishers, 2001
Reference Books
1. Thomas L. Floyd, Digital Fundamentals, Pearson Education, 11th Edition, 2015. 2. Jacob Fraden, Handbook of Modern Sensors, Springer, 4th Edition, 2010. 3. Robert L Boylestad, Electronic Devices & Circuit Theory, Pearson Education, 11th Edition, 2013.

Semester II

Course Name- Robot Dynamics and control

Course Code- SR 607

Course Code	Course Name	L – T – P	Credits
SR 607	***Robot Dynamics and control***	3-1-0	**4**
Course Objectives: · Understand robot kinematics: transformations, forward/inverse kinematics, Jacobians, trajectory generation for serial/parallel mechanisms. · Learn robot dynamics: Lagrange-Euler, Newton's equations, state-variable representations, dynamics with actuators. · Explore robot control: regulator, tracking problems, controllers for set point tracking, actuator saturation, anti-windup compensation, optimal control. · Study nonlinear dynamics/control: Lyapunov stability, robust control, feedback linearization, variable-structure controllers. · Understand inverse dynamics, force control, stiffness/impedance control, hybrid position/force control, under-actuated systems.			
Unit I: Review of Robot Kinematics- Transformations: Joint/Task space, Forward Kinematics, Inverse Kinematics, Jacobians, Trajectory Generation, Serial and Parallel Kinematics.			

Unit II: Robot Dynamics- Lagrange-Euler Dynamics, Force, Inertia, and Energy, Lagrange's Equations of Motion, Newton's equations of motion, Formulation of robot dynamics, State-Variable Representations, Dynamics of robots with actuators.

Unit III: Robot control problems – Regulator problem, tracking problem, controllers. Set point Tracking, Actuator Saturation, Integrator Anti-windup Compensation, Quadratic Optimal control problem.

Unit IV: Nonlinear dynamics and control - Lyapunov stability theorem, Robust control, Feedback Linearization Controllers, Lyapunov Designs, Variable-Structure Controllers, Saturation-Type Controllers.

Unit V: Inverse dynamics controllers, Force control, Stiffness control, Impedance control, Hybrid Position/Force Control, Reduced state modeling and control, Impedance Control, Stiffness and Compliance, Under-actuated System.

Unit VI: Case Studies.

Course Outcomes

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

1. **CO1:** Apply kinematic transformations, solve forward/inverse kinematics, generate trajectories for serial/parallel robots.
2. **CO2:** Formulate and solve robot dynamics using Lagrange-Euler, Newton's equations, state-variable representations.
3. **CO3:** Analyze and design controllers for set point tracking, actuator saturation, anti-windup compensation.
4. **CO4:** Implement nonlinear control: Lyapunov stability, robust control, feedback linearization.
5. **CO5:** Design inverse dynamics controllers, force/stiffness control, impedance control for under-actuated systems.

Text Books

1. Francis N-Nagy Andras Siegler, Engineering foundation of Robotics, Prentice HallInc., 1987
2. John J. Craig, Introduction to Robotics Mechanics and Control, Second Edition, Addison Wesly Longman Inc. International Student edition,1999
3. M.P. Groover , Mitchel Weiss, “Industrial Robotics: Technology, Programming and Applications”(2e), McGraw Hill ,2012

Reference Books

1. 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
4. P.A. Janaki Raman, Robotics and Image Processing an Introduction, Tata Mc Graw Hill Publishing company Ltd.,1995
5. Bernard Hodges, Industrial Robotics, Jaico Publishing house, 2nd Edition,1993.
6. Tsuneo Yohikwa, Foundations of Robotics Analysis and Control, Prentice Hall of India Pvt. Ltd.,2001.
7. Bijay K.Ghosh, NingXi,T.J.Tarn, Control in Robtics and Automation Sensor-Based integration, Academic Press,1999

Course Name: AI & Machine Learning in Robotics

Course Code: SR 613

Course Code	Course Name	L – T – P	**Credits**
SR 613	***AI & Machine Learning in Robotics***	3-1-0	**4**

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. **Unit VI:** Reinforcement learning, case studies in the area of robotics.
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.
Text Books
1. Artificial Intelligence: a modern approach, Stuart Russell & Peter Norvig, Prentice Hall, 3rd Edition, 2009. 2. Artificial Intelligence, E. Rich and K. Knight, 2nd ed., McGraw-Hill, New York, 1991.
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. 4. Artificial intelligence: a modern approach, Stuart Russell and Peter Norvig, 2002. 5. Soft Computing :Fundamentals and applications, D K Pratihar Narosa Publishing House 2015

Elective Subjects

Course Name- Programming languages for Robots

Course Code-SR 604

Course Code	Course Name	L – T – P	**Credits**
SR 604	***Programming languages for Robots***	3-1-0	**4**

Course Objectives:

· Understand programming fundamentals: languages (machine-level, assembly, high-level), data types, variables, operators, expressions, conditional statements, and program structures.

· Explore Robot software functions: coordinate systems, position control, control functions, subroutines, online/offline programming, and lead-through methods.

· Introduce Robot Operating System (ROS): packages, launch files, key concepts (services, actions, nodes), publisher-subscriber model, debugging, and environment setup.

· Learn basics of MATLAB/Python and Introduction to Arduino: interfacing, parallel/serial/USB concepts, and basics of robot control with Arduino.

· Explore real-time applications in mobile robotics.

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/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, MATLAB programming - 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:

· **CO1:** Demonstrate proficiency in programming fundamentals across multiple languages and understand data handling and control structures.

· **CO2:** Apply Robot software functions including coordinate systems, position control, and motion interpolation techniques in programming tasks.

· **CO3:** Utilize Robot Operating System (ROS) effectively by creating and debugging nodes, managing packages, and understanding service-oriented architecture.

· **CO4:** Implement basic programming tasks using MATLAB/Python and Arduino, and interface Arduino with MATLAB for sensor interfacing and control applications.

· **CO5:** Apply image processing techniques in MATLAB for tasks such as segmentation, enhancement, feature extraction, object tracking, and recognition in robotic applications.

Text /Reference Books

1. Mikell P. Groover, Mitchell Weiss, Roger N. Nagel and Nicholas G. Odrey, '*Industrial Robotics Technology, Programming and Applications*', McGraw Hill Book company, 1986.
2. Bernard Hodges, '*Industrial Robotics*', Second Edition, Jaico Publishing House, 1993.

Reference Books

1. A.K.Gupta, S K Arora,'*Industrial Automation and Robotics*', University science press,2012.
2. R. C. Gonzalez, R. E. Woods and S. L. Eddins, *'Digital Image Processing Using MATLAB',*Gatesmark Publishing , 2020.

Course Name-Machine Vision and Image Processing

Course Code-SR 608

Course Code	Course Name	L – T – P	**Credits**
SR 609	**Machine vision and Image processing**	3-0-1	**4**

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 sensor fusion methods, and their applications in robotic vision systems.

Unit I: Architecture of Robotic vision system, Image acquisition, representation, processing Data Acquisition, Conversion, Transmission and Processing: Inertial sensors, Laser Scanners 2D and 3D, Robot Vision, 3D cameras, filters for removal of noise and, INS, gyroscopes,2D,3D Scanner platforms.

Unit II: Image acquisition and analysis, Vision and image sensors, digitization, preprocessing, vision system components, basic optics, basic radiometry, image formats, image noise, image representation, color space, conversion of color spaces.

Unit III: 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, discrete cosine transform to images, 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, 3d reconstruction.

Unit V: Motion estimation and tracking: Optical flow estimation, the concept of sensor fusion - Kalman filter, Localization and Mapping techniques, object tracking with Kalman filtering, feature extraction & object recognition

Unit VI: Case studies/application: Industrial application of vision controlled Robotics systems, industrial robot guidance, demonstration of applications using computer vision toolbox and image processing toolbox.

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.
Text Books
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. 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. Boguslaw Cyganek& J. Paul Siebert, *An Introduction to 3D Computer Vision Techniques and Algorithms*, Wiley, 2009.

Course Name: Advanced Control system

Course code: SR 611

Course Code	Course Name	L – T – P	**Credits**
SR 611	***Advanced Control system***	3-1-0	**4**

Course Objectives: · Understand model-based controller design principles, including control structures, performance measures, PID controller limitations, and effects of noise and load. · Explore frequency domain-based identification techniques using relay control systems, and conduct off-line and on-line dynamic model identification. · Learn time domain-based state space identification methods, focusing on FOPDT, SOPDT models, and the identification of under-damped systems. · Study steady-state gain determination, SOPDT model identification with pole multiplicity, limit cycles in unstable systems, and techniques for identifying TITO (Two Input Two Output) systems. · Review and apply time and frequency domain-based identification methods, including on-line identification and advanced techniques such as Fourier series and wavelet transform for improved model parameter accuracy.

Unit I: Model Based Controller Design, Control structures and performance measures, Time and frequency domain performance measures, Design of controller, Design of controller for SISO system, Controller design for TITO processes, Limitations of PID controllers, PI-PD controller for SISO system, PID-P controller for Two Input Two Output system, Effects of measurement noise and load

Unit II: Frequency Domain Based Identification: Identification of dynamic models of plants, Relay control system for identification, Off-line identification of process dynamics, On-line identification of plant dynamics.

Unit III: Time Domain Based Identification: State space based identification, State space analysis of systems, State space based identification of systems -1, State space based identification of systems -2, Identification of simple systems, Identification of FOPDT model, Identification of second order plus dead time model, Identification of SOPDT model,

Unit IV: Steady state gain from asymmetrical relay test, Identification of SOPDT model with pole multiplicity, Existence of limit cycle for unstable system, Identification procedures, Identification of under damped systems, Off-line identification of TITO systems, On-line identification of TITO systems,

Unit V: Review of time domain based identification, DF based analytical expressions for on-line identification, Model parameter accuracy and sensitivity, Improved identification using Fourier series and wavelet transform, Reviews of DF based identification,

Unit VI: Design of Controllers: Advanced Smith predictor controller, Design of controllers for the advanced Smith predictor, Model-free controller design, Model based PID controller design, Model based PI-PD controller design, Tuning of reconfigurable PID controllers

Course Outcomes

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

· **CO1:** Apply principles of model-based controller design to analyze control structures, evaluate performance measures, and design controllers for both SISO (Single Input Single Output) and TITO systems.

· **CO2:** Implement frequency domain-based identification techniques to estimate dynamic models, performing both off-line and on-line identification of process dynamics.

· **CO3:** Utilize state space analysis for time domain-based identification, effectively modeling systems and identifying various models including FOPDT, SOPDT, and under-damped systems.

· **CO4:** Determine steady-state gains, identify SOPDT models considering pole multiplicity, analyze and mitigate limit cycles in unstable systems, and apply identification procedures tailored for TITO systems.

· **CO5:** Evaluate the strengths and limitations of time and frequency domain-based identification methods, implement on-line identification strategies, and enhance accuracy using advanced techniques such as Fourier series and wavelet transform in practical applications.
Text Books
1. S. Majhi, Advanced Control Theory-Relay Feedback Approach, Cengage Asia/IndiaPvt.Ltd, 2009.2. 2. A. Johnson and H. Moradi, New Identifications and Design Methods, Springer - Verlag, 2005.3.
Reference Books
1. Norman S. Nise, Control Systems Engineering, John Wiley & Sons, 2008

Course Name: Design aspect of Automation

Course code: SR 612

Course Code	Course Name	L – T – P	**Credits**
SR 611	***Advanced Control system***	4-0-0	**4**
Course Objectives: · Understand mechatronics fundamentals and design automated systems with proper component selection and fabrication. · Learn electromechanical system performance terms, use CAD for component design, and apply various fabrication methods. · Explore measurement systems using potentiometers, displacement, position, and proximity sensors for precise environmental measurements. · Study signal conditioning, microprocessor technology, including amplification, filtering, pulse modulation, and basic programming. · Investigate electrical drives, motor types (DC, AC, stepper, servo), industrial mechanisms, and ball screw-driven motion in automation.			
Unit I: Introduction, Basic concepts, Mechatronics, Design of automated systems, Mechatronics based systems, Automated systems and equipment used in manufacturing, selection and fabrication, selection of electrical and electronics components for Mechatronics based systems,			

Unit II: terms related to performance of electro mechanical systems, computer aided design of components, fabrication processes, Measurement system and potentiometer sensors, Displacement position and proximity sensor, fluid flow pressure and temperature measurement. **Unit III:** Signal conditioning and microprocessor technology, signal conditioning, amplification, filtering, pulse modulation, protection devices and wheastone bridge, signal conversion, microprocessor technology, introduction to microprocessor programming, **Unit IV**: Electrical drives, application of electric drives in automation, DC and AC motors, stepper motor and servo motor, Mechanisms: types of industrial automation mechanisms, Ball screw based linear motion drives, **Unit V**: Application of camsin automation, Application of indexing mechanisms in automation, Application of tool magazine in automation, material handling systems, Hydraulic systems, fundamental concepts, hydraulic pumps, Control valves and graphical representation, direction control valves, flow control and pressure relief valves, graphical representation of hydraulic system elements, **Unit VI**: Pneumatic systems, basic concepts and air compressors, air treatment and pressure regulation, graphical representation and pneumatic circuits, computer aided manufacturing and process planning, CNC machine and interpolation.
Course Outcomes
After completing this course, the students will be able to: · **CO1:** Design and fabricate automated systems using mechatronics principles and appropriate components. · **CO2:** Analyze electromechanical system performance, use CAD for component design, and apply diverse fabrication techniques. · **CO3:** Implement measurement systems with precise sensors for positional and environmental data. · **CO4:** Design signal conditioning circuits, utilize microprocessors for control, and program them for basic automation. · **CO5:** Apply electrical drives, understand various motor types, and implement ball screw-driven motion effectively in automation.
Text Books
1. Bishop, R. H. (Ed.). (2017). "*Mechatronics: an introduction*", CRC Press. 2. Ogata, K. (2004). *System dynamics* (Vol. 13). Upper Saddle River, NJ: Pearson/Prentice Hall.
Reference Books
1. Bernard Hodges, "*Industrial Robotics*", Jaico Publishing house, 2nd Edition,1993. 2. Richard D. Klafter, Thomas. A, Chmielewski, Michael Negin, "*Robotics*

Engineering an Integrated Approach", Prentice Hall of India Pvt. Ltd.,1989.

Course name- Swarm Robotics
Course code-SR 614

Course Code	Course Name	L – T – P	**Credits**
SR 614	***Swarm Robotics***	4-0-0	**4**

Course Objectives:

· Understand and apply ant colony optimization (AS, ACS, Max-Min AS) and Particle Swarm Optimization (PSO) for solving complex optimization problems.

· Explore neural networks including perceptrons, multilayer perceptrons, recurrent networks, and their training methods.

· Investigate self-organization in physical systems and its application in swarm intelligence for robotics and material science.

· Design algorithms for embodied swarm intelligence, considering topology, specification, and PSO tuning.

· Study synchronization challenges in computational systems with communication delays through case studies.

Unit I: Swarm Intelligence - from computational to physical intelligence, Introduction, Definition, Ant Colony Optimization, Biological Inspiration Computationally Hard Path Planning problems, The Ant Colony Optimization Meta-heuristic, Ant System (AS), Ant Colony System (ACS) and Max-Min Ant System.

Unit II: Particle Swarm Optimization, Biological inspiration, Convergence Evolutionary Algorithms, Genetic representation of a problem.

Unit III: Neural network: Biological background, A single layer perception, Multilayer perception, Recurrent neural network, Training of neural networks. Self-organization in physical system, Swarm intelligence in robotics systems, Robotic material

Unit IV: Designing algorithm for embodied swarm intelligence, topology and algorithm specification, PSO tuning,

Unit V: Task allocation, Optimal task allocation, Response threshold task allocation, Market based algorithms

Unit VI: Synchronization of computational systems with communication delays, case studies

Course Outcomes
After completing this course, the students will be able to: · **CO1:** Apply AS, ACS, Max-Min AS, and PSO to solve computationally hard path planning and optimization problems effectively. · **CO2:** Implement neural networks like perceptrons and multilayer networks for pattern recognition and prediction tasks. · **CO3:** Apply self-organization principles to design effective swarm intelligence algorithms for robotics and material science applications. · **CO4:** Develop optimized algorithms for task allocation using swarm intelligence principles. · **CO5:** Analyze and mitigate synchronization issues in computational systems with communication delays using practical case studies.
Text Books
1. Swarm Intelligence: From natural to artificial systems. E. Bonabeau, G. Theraulaz, and M. Dorigo, 1999. 2. Self-Organization in Biological Systems, Camazine, Deneubourg, Franks, Sneyd, Theraulaz, Bonabeau, 2003.
Reference Books
1. Floreano, Dario, and Claudio Mattiussi. Bio-inspired artificial intelligence: theories, methods, and technologies. MIT press, 2008. 2. Decentralized Spatial Computing, M. Duckham, Springer, 2013

Course Name- Introduction to Humanoid Robotics

Course Code- SR 615

Course Code	Course Name	L – T – P	**Credits**
SR 615	***Introduction to Humanoid Robotics***	4-0-0	**4**
Course Objectives: · Gain understanding of humanoid robotics: properties, kinematic equations, and rotational motion characteristics. · Learn biped locomotion fundamentals: legged robot configurations, gait patterns, stability criteria, ZMP dynamics. · Master two-dimensional walking pattern generation and control principles for humanoid robots on varied terrain. · Explore hardware components, robot vision, behavior-based robotics, and human-robot interaction in social contexts.			

· Analyze humanoid robot applications in healthcare, education, defense, space, and agriculture.

Unit I: Introduction to Humanoid Robotics, Understanding of specific properties of humanoid robots, and state-of-the-art, Kinamatic equation for basic robot systems-Coordinate transforms, Homogeneous transforms Characteristics of Rotational Motion. Velocity in Three Dimensional Space. Robot Data Structure and Programming, Kinematics of a Humanoid Robot.

Unit II: Biped locomotion fundamentals- Configuration of legged Robots, Terminologies of locomotion-Single support phase, double support phase, support polygon, Gait pattern, Gait stability criteria, Static and dynamic stability of humanoid robot systems, ZMP and Ground Reaction Forces, Measurement of ZMP Dynamics of Humanoid Robots Humanoid Robot Motion. Angular Momentum and Inertia Tensor of Rigid Body.

Unit III: Two Dimensional Walking Pattern Generation, Two Dimensional Inverted Pendulum, Planning a Simple Biped Gait, Extension to a Walk on Uneven Terrain, ZMP Based Walking Pattern Generation, Stabilizer-Principles of Stabilizing Control, reconfiguration of legged robots.

Unit IV: Hardware for humanoid Robots, Robot vision, behavior based robotics, Human robot interaction and social Robotics, learning for intelligent robotic manipulator, cognitive intelligence for Human-robot teaming

Unit V: Humanoid applications in healthcare, teaching, military, space, agriculture.

Unit VI: Real life Case studies.

Course Outcomes

After completing this course, the students will be able to:
CO1: Apply kinematic equations and transforms to model humanoid robot motion and programming.

CO2: Evaluate stability and dynamics of bipedal locomotion systems using ZMP and gait analysis.

CO3: Design walking patterns and control strategies for bipedal robots on different terrains.

CO4: Integrate hardware components, vision systems, and behavioral algorithms in humanoid robotics.

CO5: Assess applications of humanoid robots in diverse fields through real-life case studies.

Text Books

1. Shuuji Kajita·Hirohisa Hirukawa Kensuke Harada·Kazuhito Yokoi, "*Introduction to Humanoid Robotics*", springer,2014.

Reference Books
1. Ambarish Goswami Prahlad Vadakkepat, "*Humaniod Robotics*",Springer reference,2019

Course Name- Field and service Robots

Course Code-SR 616

Course Code	Course Name	L – T – P	**Credits**
SR 616	***Field and service Robots***	4-0-0	**4**

Course Objectives:

· Explore field and service robots' history, trends, and future, focusing on non-conventional industries. Study mobile robots' kinematics, perception, and control.

· Investigate field robots for agriculture, mining, exploration, underwater tasks, and industrial applications like cleaning and painting.

· Study underwater robots, including kinematics, dynamics, navigation, and marine data collection.

· Explore aerial robots, covering sensors, actuators, modeling, control, and navigation for small UAVs.

· Analyze autonomous flight control systems for aerial robots in defense and other applications.

Unit I: Introduction to Humanoid Robotics, Understanding of specific properties of humanoid robots, and state-of-the-art, Kinamatic equation for basic robot systems-Coordinate transforms, Homogeneous transforms Characteristics of Rotational Motion. Velocity in Three Dimensional Space. Robot Data Structure and Programming, Kinematics of a Humanoid Robot.

Unit II: Biped locomotion fundamentals- Configuration of legged Robots, Terminologies of locomotion-Single support phase, double support phase, support polygon, Gait pattern, Gait stability criteria, Static and dynamic stability of humanoid robot systems, ZMP and Ground Reaction Forces, Measurement of ZMP Dynamics of Humanoid Robots Humanoid Robot Motion. Angular Momentum and Inertia Tensor of Rigid Body.

Unit III: Two Dimensional Walking Pattern Generation, Two Dimensional Inverted Pendulum, Planning a Simple Biped Gait, Extension to a Walk on Uneven Terrain, ZMP Based Walking Pattern Generation, Stabilizer-Principles of Stabilizing Control, reconfiguration of legged robots.

Unit IV: Hardware for humanoid Robots, Robot vision, behavior based robotics, Human robot interaction and social Robotics, learning for intelligent robotic manipulator, cognitive intelligence for Human-robot teaming

Unit V: Humanoid applications in healthcare, teaching, military, space, agriculture. **Unit VI:** Real life Case studies.
Course Outcomes
After completing this course, the students will be able to: CO1: Analyze the historical evolution and current status of service robotics, predicting future trends and innovations. CO2: Apply principles of kinematics, perception, and motion planning to design autonomous mobile robots capable of intelligent decision-making. CO3: Evaluate the design considerations and operational challenges of field robots across diverse applications, ensuring performance, safety, and robustness. CO4: Demonstrate proficiency in designing and implementing navigation and control systems for underwater robots, integrating environmental data collection capabilities. CO5: Design and develop guidance and control systems for aerial robots, ensuring effective navigation and operation in various environments, including autonomous indoor flight.
Text Books
1. Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza, Introductionto Autonomous Mobile Robots, Bradford Company Scituate, USA, 2004 2. Riadh Siaer, The future of Humanoid Robots- Research and applications, Intech Publications,20
Reference Books
1. Richard D Klafter, Thomas A Chmielewski, Michael Negin, "*Robotics Engineering AnIntegrated Approach*", Eastern Economy Edition, Prentice Hall of India PLtd. ,2006. 2. Kelly, Alonzo; Iagnemma, Karl; Howard, Andrew, *Field and Service Robotics*, Springer,2011.

Course Name- Aerial Robotics
Course Code- SR 617

Course Code	Course Name	L – T – P	**Credits**
SR 617	***Aerial Robotics***	3-1-0	**4**

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, different type of multi-rotor UAV configurations.

Unit II: Reference frames, Rotational matrices, UAV-kinematics.

Unit III :UAV-forces and moments, UAV dynamics, Six-degree-of-freedom equations of motion, 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, modalde composition, transfer function models, first and second-order systems, time response, frequency response, root locus, bode plot

Unit VI : Vision-based navigation, waypoint following.

Course Outcomes

After completing this course, the students will be able to:
CO1: Demonstrate proficiency in configuring and operating multi-rotor UAVs, understanding their dynamics, and applying kinematic principles.

CO2: Analyse and design longitudinal and lateral autopilot systems, including pitch-rate damping, altitude hold, and coordinated turns.

CO3: Model and analyse LTI systems using state-space and transfer function representations, evaluating time and frequency domain characteristics.

CO4: Apply root locus and Bode plot techniques to assess stability and performance of UAV control systems.

CO5: Implement vision-based navigation algorithms for accurate waypoint following in UAV missions, integrating sensor data for real-time decision making.

Text Books

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. 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 Name- Robotic Path Planning and Control

Course Code- SR618

Course Code	Course Name	L – T – P	**Credits**
SR 618	***Robotic Path Planning and Control***	3-1-0	**4**

Course Objectives:

· Understand and apply ant colony optimization (AS, ACS, Max-Min AS) and Particle · Learn path planning techniques: Bug algorithms, C-space planning, Potential Fields, A* and D* algorithms, and Rapidly Exploring Random Trees.

· Understand trajectory generation: Cubic polynomials, linear functions, and Cartesian space schemes.

· Study linear robot control: Joint control, trajectory following, PID control.

· Explore nonlinear manipulator control: Coulomb friction, feedforward control, stability analysis.

· Investigate force control: Hybrid position/force control, compliance mechanisms.

Unit I: Swarm Intelligence - from computational to physical intelligence, Introduction, Definition, Ant Colony Optimization, Biological Inspiration Computationally Hard Path Planning problems, The Ant Colony Optimization Meta-heuristic, Ant System (AS), Ant Colony System (ACS) and Max-Min Ant System.

Unit II: Particle Swarm Optimization, Biological inspiration, Convergence Evolutionary Algorithms, Genetic representation of a problem.

Unit III: Neural network: Biological background, A single layer perception, Multilayer perception, Recurrent neural network, Training of neural networks. Self-organization in physical system, Swarm intelligence in robotics systems, Robotic material

Unit IV: Designing algorithm for embodied swarm intelligence, topology and algorithm specification, PSO tuning,

Unit V: Task allocation, Optimal task allocation, Response threshold task allocation, Market based algorithms

Unit VI: Synchronization of computational systems with communication delays, case studies

Course Outcomes

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

· **CO1:** Apply Bug algorithms, Potential Field methods, and visibility-based planning techniques to solve path planning problems in robotics.

· **CO2:** Implement trajectory generation methods such as cubic polynomials and Cartesian space schemes to generate smooth robot trajectories with specified constraints.

· **CO3:** Design and implement linear control strategies for robots, including trajectory following, PID control, and disturbance rejection.

· **CO4:** Develop nonlinear control strategies for manipulators to handle complexities like Coulomb friction, multi-input dynamics, and adaptive control in industrial settings.

· **CO5:** Implement force control techniques including hybrid position/force control and compliance mechanisms for tasks requiring precise force application and interaction with the environment.

Text Books

1. John J. Craig, *Introduction to Robotics Mechanics and Control*, 3rd Edition, Pearson, 2008.
2. Latombe, Jean-Claude. *Robot motion planning*. Vol. 124. Springer Science & Business Media, 2012.
3. K. Ogata, *Modern Control Engineering*, 5th Edition, Prentice Hall, 2010

Reference Books

1. B. Friedland, *Control System Design-An Introduction to State Space Methods,* McGraw- Hill, Singapore, 1987
2. J.J.E Slotine and W. Li, *Aplied Nonlinear Control*, Prentice-Hall, NJ, 1991
3. M. W. Spong and M. Vidyasagar, *Robot Dynamics and Control*, John Wiley & Sons, NY, USA, 2004
4. Howie M Choset, Seth Hutchinson, Kevin M Lynch, George Kantor, Wolfram Burgard, Lydia E Kavraki, Sebastian Thrun *Principles of Robot Motion: Theory, Algorithms, and Implementation*, 2005

Department of Computer Science & Engineering

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING (CSE)

ABOUT CSE

In the evolving landscape of technological advancement, the Department of Computer Science & Engineering (CSE) at DIAT was established in 1987, marking the beginning of a journey in innovation and progress. The department introduced its first MTech course in 2009, with a mission to contribute to the fields of Cyber Security, Artificial Intelligence, and Computing techniques. Our goal is to embrace modern digital advancements, fostering a future guided by innovation, critical thinking, and scientific excellence. Today, the CSE department continues to build upon its rich legacy with humility.

The CSE Dept. offers a tapestry of **THREE Post-Graduation academic programs** and research ventures, a testament of commitment to diversity and multidisciplinary. From M.Tech., MS by Research, M.Sc., to Ph. D programs are tailored for scientists of R&D organisations, officers of Tri-Services, GATE-Qualified candidates, & self-financed scholars. The offerings are diverse as the ever-evolving world of technology. Among our flagship **M.Tech. programs** are **Cyber Security**, **CSE** (**Artificial Intelligence**), and **M. Sc** (**IT**) at **INS HAMLA**.

Research in CSE isn't just a buzzword; it's the heartbeat. It is on the forefronts of cutting-edge research, impart niche-area trainings, actively managing funded projects and, since 2021 ahead in revenue generations. The CSE has received accolades for recognitions via patents & publications; in various national & international level Hackathons, Conferences & Seminars, Sports & Cultural events. The CSE is the driving force behind the Data Centre activities, facilitating internet access, emails, and IT related services for DIAT.

The dynamic community of CSE comprises approximately 80 plus post-graduate students per year; fuelled by the boundless curiosity of successful 20 Ph.D. completions since 2014 till date. 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. The 06 faculty members are luminaries in fields ranging from Cyber Security, Artificial Intelligence, Data Security to Ethical hacking, Cryptography, Blockchain technology, Quantum Computing, and the rigorous programming capabilities.

The CSE's dedication extends beyond the walls of DIAT. We are championing **ATMA-NIRBHAR BHARAT INDIA@75** with **PAN-INDIA Certification Courses** in Artificial Intelligence (self-paced 12 Weeks) & Cyber Security (16 Weeks). CSE proudly stand to contribute for MHRD skill development programmes by educating 3000plus candidates, since 2021 till date. The customised programs for Tri-Services and other national organisations underscore CSE's commitment to empowerment and growth to build self-reliant nation. With resounding emphasis on research, interdisciplinary collaborations, and a global outlook, CSE 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 dept. where innovation know no bounds!

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 4 credits is delivered by subject experts over the duration of 16 weeks approximately. It consists of 3 hrs. of classroom interaction and 2 hrs. of lab sessions per week. The evaluations follow a continuous assessment process that includes – 3 monthly evaluation exams (10 Marks each), an internal assessment (20 Marks), and a final examination (50 Marks). The lab focuses on practical exposure to the Cyber Security tools and techniques in the form of mini-projects and lab assignments. The 3rd and 4th semesters have a major component of M.Tech. project dissertation, 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.

Program Educational Objectives (PEOs)

PEO1 The M.Tech. courses of SoCE&MS aim at developing skilled Human Resources in the field of Digitization by providing different specializations in M&S, DS, 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.

SEMESTER I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	CS 601	Data Security & Privacy	3	1	4
2	CS 602	Machine Learning for Cyber Security	3	1	4
3	CS 603	Applied Cryptography	3	1	4
4	CS 604	Advanced System Security	3	1	4
5	CS 605	Network and Cloud Security	3	1	4
6	AM 607	Mathematics for Engineers	3	1	4
7	PGC 601	Research Methodology and IPR	2	0	2
		Total	**20**	**6**	**26**

SEMESTER II

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	CS 611	Digital Forensics	3	1	4
2	CS 612	Reverse Engineering & Malware Analysis	3	1	4
3		Elective – I (From Department)	3	1	4
4		Elective – II (From Department)	3	1	4
5		Elective – III	3	1	4
6		Elective – IV	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	**20**	**6**	**26**

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	CS 651	M.Tech. Dissertation Phase-I	28		14
		Total	**28**		**14**

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	CS 652	M.Tech. Dissertation Phase-II	28		14
		Total	**28**		**14**

List of Electives/Open Electives (Applicable for Sem - II):

Sr.No.	Course Code	Course
1.	CS 613	Security Standards & Penetration Testing
2.	CE 695A	Cyber Physical Systems
3.	CE 70G	Blockchain Technology
4.	CE 66A	Algorithmic Cryptanalysis
5.	CE 606A	Software Engineering & System Modelling
6.	CE 699	Internet of Things
7.	CE 681	Mobile Computing
8.	CE 683	Information Warfare
9.	CE 689	Fault Tolerant Computing Systems
10.	CE 690	Parallel & Distributed Systems
11.	CE 688	Game Theory
12.	CE 667	Trustworthy Computing
13.	CE 692	Computational Geometry & Applications
14.	CE 698	Multimedia Security
15.	CE 695	Cyber-Physical & Self-Organizing Systems
16.	CE 69B	Network Forensics
17.	CE 602A	Computational Intelligence
18.	CE 70A	Formal Specification and Verification of Programs
19.	CE 70B	Advanced Algorithms
20.	CE 700	Quantum Computing
21.	CE 70D	Computer Network Audit & Forensics
22.	CE 697	Biometric Security
23.	CE 70E	Machine Learning in Python
24.	CE 70F	Cloud Computing

25.	CE 70H	Cyber Security and Cryptography for Embedded Systems
26.	CE 682	Secure Software Engineering
27.	CE 69F	Theory of Computation
28.	CE 691	Secure Wireless Sensor Networks
29.	*AM 625*	*Digital Image Processing*
30.	*AM 628*	*Computational Number Theory and Cryptography*
31.	*EE 613*	*Electronic Warfare*
32.	*TM 609*	*System Engineering*
33.	*MOOC*	*Any relevant MOOC course for 4 credits upon*

Course Code	Course Name	L – T – P	**Credits**
CS-601	**Data Security & Privacy**	3-0-2	**4**

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 SecurityOfficer 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 wasforeseeable).
- 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 andalso focus on specific technologies.

About theCourse:

- As data collection and information networks expand (and stories of security breaches and the misuse of personal information abound), data security and privacy issues are increasingly central parts of the information policy landscape.
- Legislators, regulators, businesses, and other institutions of all kinds are under increasing pressure to draft and implement effective laws, regulations, and security and privacy programs under rapidly changing technological, business, and legal conditions.
- A strong need is arising for individuals with the training and skills to work in this unsettled and evolving environment.
- This course will examine: 1) security issues related to the safeguarding of sensitive personal and corporate information against inadvertent disclosure; 2) policy and societal questions concerning the value of security and privacy regulations, the real world effects of data breaches on individuals and businesses, and the balancing of interests among individuals, government, and enterprises; 3) current and proposed laws and regulations that govern information security and privacy; 4) private sector regulatory efforts and self- help & system design measures; 5) emerging technologies that may affect security and privacy concerns; and 6) issues related to the development of enterprise data security programs, policies, and procedures that take into account the requirements of all relevant constituencies; e.g., technical,

business, and legal.

- This course is intended for students and professionals in information policy, public policy, business, and information science who have an interest in work or research in security and privacy fields, or in support of those fields.
- Along with traditional responsibilities individuals may have new security considerations, e.g., programming. The course will include individual reading and writing assignments, class discussion, case studies, and a group assignment. Students will have some latitude to tailor the assignments to theirskills and interests.

Course Contents	
Unit I (8 Hrs; T1:CH1, T2:CH1) Security Architectures Information Systems; Database management Systems; Information Security CIA; Information Security Architecture; Database Security levels' Menances to Databases; Asset Types & their values.	CO1
Unit II (4 Hrs; T1:CH1, T2:CH2,3) **Database Security Methods Environments:** Parallel DBs, Distributed DBs, Database security Methodology; Database Security Definition.	CO1
Unit III (6Hrs; T1:CH4, T2:CH4) Profiles, Password Policies, Privileges, and Roles Defining and using Profiles: Creating Profiles in SQL Servers & end-users; Password Policies, Privileges, Tables and DatabaseObjects Privileges, Column-Level Privileges; Creating, Assigning, and Revoking User Roles	CO1, CO2
Unit IV (6 Hrs; T1:CH5, T2:CH4) **Database Application Security Models:** Security Models: Access Matrix Model, Access Modes Models; Application Types: Client/Server Application; Web Application, Data Warehouse, Data Stream Applications	CO3
Unit V (6 Hrs; T1:CH6) **Virtual Private Databases:** VPD, Implementation, VPD Row Col Security**.**	CO3
Unit VI (6 Hrs; T1:CH7,8,9, T2:CH12,13) **Database Auditing Models** Technical Audit Environment, Process, Objectives, Classification Types, Incidence Reports, Level ofescalations. **Application Data Audit:** DML Action Audit; Triggers; Fine-Grained Auditing FGA; Application Errors; PL-SQL Environments, Audit DB Activities	CO4
Unit VII (6 Hrs; T1:CH10, T2:CH9,10,11) **Evolving Models & Security:** Big Data; Data Streams; Structured, Unstructured, SQL and NOSQL,BlockChains, NFTs; Database Trojans, SQL Attachments in e-mails; Anatomy of vulnerability SELECT Encrypt data-at-rest & data-at-transit, Dataand AIML Models.Project Cases data Security and	CO1, CO4

Privacy: OnlineDatabases; CSV files to Structured Environments, SCADA, IoTs, **Laboratory Assignments/ Demonstrations** 1 Describe the Use Case*. Model the case study. Abstract. Apply & implement DDL.(Unit-1, 02 hours) 2 Using the case-study, Apply and implement the Security Model. Analyse Threats. Wrt Roles, Access Right. (Unit-2 02 hours) 3 Apply, analyse, and evaluate ACID Properties. Identify Threats and implement a Mitigation- technique to secure the data tuples. (Unit-3 & 4 02 hours) 4 Implement and apply Multi-dimensional DBs. Implement three basic operations: Perform Diagnostic Analysis. (Unit 4 & 5; 02 hours) 5 Implement and apply Multi-dimensional DBs. Implement operations to observe 'what-if' analysis: Perform Predictive Analysis. (Unit 4 & 5 02 hours) 6 Create use case environment, Implement & Perform Audit wrt Application/Domain Control. (Unit 6 ; 02 hours) 7 Create use case environment, implement & perform audit wrt Technology. (Unit 6 02 hours) 8 Create model and implement a security feature to demonstrate data security. (Unit-7 ; 02 hours) 9 Assigned ISO module's Study, Audit and Presentation. (Unit 1 to 7Sem) 10 Mini-project. Implementation and Demonstration. Report Submission is essential. (Unit 1 to 7 Sem)	CO1 CO2 CO3 CO3 CO4 CO4 CO4 CO4 CO4 CO4
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 inconcepts 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 lawenforcement 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	
5. Hassan A. Afyouni, Database Security and Auditing , Third edition, Cengagelearning,2009 6. 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 ‖:Models and Algorithms, Kluwer Academic Publishers, 2008

Course Code	Course Name	L – T – P	**Credits**
CS-602	**Machine Learning for Cyber Security**	3-0-2	**4**

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 behavior analysis etc. Student will learn Python Programming for implementing these algorithms on standard datasets to develop tools for cyber defense using machine learning.

Prerequisite:

- Basic computer networking, operating systems and computer programming knowledge is required

Course Contents	
Unit I (12 Hrs; T1, T2) **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, Supervised, unsupervised classification and regression analysis	CO1
Unit II (12 Hrs; T2, T3) 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	CO2
Unit III (12Hrs; T2, T3, T4) 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	CO2
Unit IV (12 Hrs; T4 , T5) Unsupervised classification K-Means Clustering, Hierarchical Clustering, Density-Based Clustering, Recommender Systems- Content-based	CO3

recommender systems, Collaborative Filtering, machine learning techniques for standard dataset, ML applications, 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.	
Lab Assignments	
1 Python Programming part-1 (Unit -1;02hours)	
2 Python Programming part-2 (Unit -1 ; 02 hours)	CO1,3,4
3 Study and Implement Linear Regression Algorithm for any standard dataset	CO1,3,4
like in cyber security domain (Unit -2 ; 02 hours)	CO2, 3,4
4 Study and Implement the KMeans Algorithm for any standard dataset in cyber security domain (Unit -3 ; 02hours)	CO1,3,4
5 Study and Implement KNN for any standard dataset in cyber security domain (Unit -3 ;02hours)	CO1,4
6 Study and Implement ANN for any standard dataset in cyber security domain (Unit -3 ; 02hours)	CO2,3
7 Study and Implement PCA for any standard dataset in cyber security domain (Unit -3;02hours)	CO3, 4
8 Case Study: Use of ML along with Fuzzy Logic/GA to solve real world Problems in cyber security domain (Unit -4; 02hours)	CO2, 3
9 Mini assignment: Apply ML along with PSO/ACO to solve any real world problem in cyber security domain (Unit -4;02 hours)	
10 ML Practice Test – 1 Quiz (Unit -1,2,3,4 02hours)	CO2,3
	CO1,2,3,4

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. (PO1,PO2, PO3, PSO2)

CO2: Students will be able to understand various ML algorithms like and analyse their applications in real world (PO1,PO2, PO3, PSO2)

privacy and the increasingly interconnected issue of security;

CO3: Students will be able to understand advanced ML algorithms and techniques etc. (PO1,PO2, PO3, PSO2)

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 (PO1, PO2, PO3, PSO1, PSO2)

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**. 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 4.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**	3-0-2	**4**

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.

Prerequisite:

- Basic understanding of mathematics concept like Prime numbers, Modulus, Operations over polynomials, Vector Algebra and knowledge of any one of the programming languages(C/C++/Java/Python)

Course Contents	
Unit I (6 Hrs; T1) 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	CO3, CO4 CO1, CO3
Unit II (8 Hrs; T1) 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	CO1, CO3
Unit III (6Hrs; T1)	CO2, CO3

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	CO3, CO4
Unit IV (6 Hrs; T1) 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.	CO3
Unit V (6Hrs; T1) 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 – SignCryption. **Unit VI (6Hrs; T4)** Homomorphic Encryption, Differential Privacy, Multiparty Computation, Functional Encryption	
	CO3,4
Lab Assignments	CO3,4
Lab 1 To encrypt the text containing numbers using Playfair Cipher (Unit-1 02 hours)	CO1, 3
Lab 2 To encrypt the image containing RGB values in the pixel using playfair (Unit-1 02hours)	CO1,3
Lab 3 Programme to find the multiplicative inverse of an integer (Unit-3;02 hours)	CO1,3
Lab 4 Programme to find the polynomial inverse (Unit-3;02hours)	CO1,3
Lab 5 Programme to implement the Key expansion of Data Encryption Standard (Unit-2; 02hours)	CO2, 3
Lab 6 To encrypt the text file using the using A5 Stream cipher (Unit-2;02 hours)	CO1, 3
Lab 7 Programme for Fair Coin Toss (Unit-4; 02hours)	CO1,3
Lab 8 Develop a system to Securely Info Exchange between 2 Ends (Mini Project)(Unit-2,3,4, 5; 02hours)	CO1,3
Lab 9 Develop code for symmetric key encryption. (Unit-2, 6 ;02hours)	
Lab 10 Light weight symmetric key encryption applications. (Unit-2; 02hours)	

Course Outcomes
After completing this course, the students will be able to: **CO1:** Students are able to understand and analyse Private keys encryption schemes **CO2:** 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 are 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, 2006, Pearson Education Asia. 2. Kahate A, "Cryptography & Network Security", Tata McGraw Hill, 2004. 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, 2001. 2. "Introduction to Cryptography with Coding Theory" by Wade Trappe & Lawrence C Washington, New Jersey, Pearson Education, 2006. 3. CharlieKaufman, 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**	3-0-2	**4**

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.

Prerequisite:

- Basic Operating System concepts; Programming language- preferably C

Course Contents	
Unit I (8 Hrs; T1) **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.	CO3, CO4
Unit II (12 Hrs; T1) **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	CO2, CO4
Unit III (14Hrs; T1) **Verifiable Security Goals:** Information flow models, secrecy models, integrity models. **Secure Capability Systems:** Capability system fundamentals, Secure capability systems mechanisms. **Secure Virtual Machine Systems:** Separation kernels, sandboxing, Multiple Independent Levels of Security.	CO3, CO4
Unit IV (6 Hrs; T1,2) **Threat Vectors, Threat Intelligence,** Memory exploits, code-based attacks; buffer overflow attacks; Return-to-libc, Micro-architectural attacks Spectre and Meltdown; **Hardware Security:** H/w trojans, Root of trust, Hardware-based root of trust, Challenges in Bootstrapping trust in secure hardware and Trust worthy devices **Case Studies** of OS exploits & Security enhanced OS: student presentation & interactive sessions.	CO2,CO4
Lab Assignments	
Lab 1OS basics - UNIX commands (Unit 1 02 Hrs)	CO1,4
Lab 2User management & Access Control in Linux & Windows (Unit 1 02 Hrs)	CO1,4
Lab 3Environment Variables and SetUID (Unit 2 02 Hrs)	CO2,4
Lab 4Exploring limitations of DAC in conventional Linux / Windows, exploits (Units 1 & 2; 02 Hrs)	CO1,2,4
Lab 5Buffer Overflow; Return-oriented Programming (Unit 4 02 Hrs)	CO2,4
Lab 6Creating isolated environment - Jailing in Linux using “chroot”, sandboxing (Unit 2;02 Hrs)	CO2,4
Lab 7VM Install and Kernel Compile (Unit 3; 02 Hrs)	CO3,4
Lab 8 – Lab 10 Mini Project: Implementing Linux Security Module || Code Injection || Binary Exploitation || Kernel Backdoors and Rootkits || Realization of (any of the) Attack Vectors Units 1, 2, 3, 4 02 Hrs	CO12,3,4

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. Bhunia, S., and M. M. Tehranipoor. "The Hardware Trojan War: Attacks, Myths, and Defenses. Springer, 2018."

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-605	**Network and Cloud Security**	3-0-2	**4**

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.
- To facilitate individual in gaining knowledge on Network and Cloud Security Protocols, Appliances and systems.

• To facilitate individual in gaining hands on experience on various attacks and countermeasures	
Course Contents **Unit I (6 Hrs)** **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.	CO1, CO4
Unit II (7 Hrs) **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.	CO3, CO4
Unit III (8 Hrs) **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.	CO2, CO4
Unit IV (5 Hrs) **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	CO2, CO4

Unit V (7 Hrs) **Use Cases:** 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	CO2, CO4
LAB Assignments:	
1 Packet Sniffing and Spoofing Lab (U 1 2 hrs)	CO1,4
2 TCP attacks Lab (U 2 ;2 hrs)	CO1,4
3 Firewall Exploration Lab (U3; 2 hrs)	CO1,4
4 VPN Lab (U2; 2 hrs)	CO1,4
5 Wireshark Lab (U8; 2 hrs)	CO3,4
6 Snort: Intrusion Detection Lab U4; 2 hrs)	CO2,4
7 CyberCiege Lab (U1 ;2 hrs)	CO1,4
8 OpenSSL Exploration Lab (U2; 2 hrs)	CO1,4
9 Digital Attack Maps DOS lab (U7 ;2 hrs)	CO3,4
10 Cloud Computing Lab (U6 ;2 hrs)	CO2,4

Course Outcomes

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

CO1: Students will be able to understand and apply Network and Cloud security Concepts along with various countermeasures. (PO1, PO3, PSO1)

CO2: Students will be able to understand and apply Network and Cloud Security concepts, hardware, software, standards and policies required for an organization. (PO1, PO2, PO3, PSO1)

CO3: Students will be able to understand the importance of implementation of Network and Cloud Security protocols, Devices, policies. (PO1, PO3, PSO1)

CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in Network and Cloud Security. (PO1, PO2, PO3, PSO1, PSO2)

Text Books

1. Introduction to Algorithms, 4th Ed., 2022, Thomas H. Cormen, Charles E. Leiserson, The MIT Press.
2. Data Structures and Algorithms in Java, 4th Ed., 2004, M. Goodrich, R. Tamassia, John Wiley and Sons, Inc.
3. Introduction to Algorithms, 3rd Ed., 2009, Thomas H. Cormen, Charles E. Leiserson, Ronald L Rivest, Clifford Stein, PHI Learning.

Reference Books

1. An Introduction to Data Structures with Applications, 1986, Jean-Paul Tremblay, Paul G. Sorenson, Tata McGraw Hill.
2. Data Structures & Program Design, 1st Ed., 1998, Robert L. Kruse, Pearson.
3. Algorithms, 1st Ed., 2006, Sanjoy Das Gupta, C. H. Papadimitriou, Umesh Vazirani. Tata McGraw Hill.

Course Code	Course Name	L – T – P	**Credits**
CS-611	**Digital Forensics**	3-0-2	**4**

Prerequisite: Knowledge of OS, Assembly Languages like Python, Number System and their Conversions, Internal Structure of CD/DVD	
Course Contents	
Unit I: **(12 Hrs; T1)** 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, and Reporting Standards,Online and Live Forensics	CO1, CO4
Unit II: **(12 Hrs; T3)** Forensic study of database and their metadata, database contents, log-files for creating timeline or recover relevant information	CO3, CO4
Unit III : (12 Hrs; T2) MFT & Registry Hives Extraction from Windows OS through Tools and ScriptsData 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	CO2, CO4
Unit IV: (12 Hrs; T2) Drone Forensics: Internal and External Memory Artifacts Analysis of DJI Drone Models, Study of Various Drone- Components and their Artifacts, Fly-Path Reconstruction, irectory Analysis, Telemetry Data Recovery from Internal and External Memory of particular Drone Model	CO2, CO4
Lab Assignments	
1.Perform Imaging and Analysis of Non-Volatile Memory using Open Source Tools in the absence of Write-Blockers. (Unit I; 02Hrs)	CO1, CO4
2.Perform Imaging and Analysis of Non-Volatile Memory using EnCase/Other Open Source Tools With and Without Write Blockers. (UnitI 02Hr)	CO1, CO4
3.Explore the Phases of Ethical Hacking in terms of implementing some attack. (Unit I 02Hr)	CO1, CO4
4.Perform Imaging and Analysis of Volatile Memory using EnCase/Other Open Source Tools (UnitI 02Hr)	CO1, CO4
5.MFT & Registry Hives Extraction from Windows OS through Tools and Scripts. (UnitII 02Hr)	CO3, CO4
6.Recovering Deleted File from the File System (UnitII 02Hr)	

7.SystemHiding Data into Slack Space. (UnitII 02Hr) 8.Data Recovery and Secure deletion on Storage media. (UnitIII 02Hr) 9.Data Carving Using Open Source Tools (UnitIII 02Hr) 10.Information gathering and network traffic analysis using TCP DUMP and WIN DUMP (UnitIII 02Hr)	CO3, CO4 CO3, CO4 CO2, CO4 CO2, CO4 CO2, CO4
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. Marshell, 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 3. Pavan Duggal, "Cyberlaw–The Indian Perspective", 2009 Edition	

Course Code	Course Name	L – T – P	**Credits**
CS-612	**Reverse Engineering & Malware Analysis**	3-0-2	**4**

Course Objective:

The course introduces reverse engineering techniques and further examines the use of reversing for detecting, analyzing, and eradicating malware. It involves:

I. Learning low level details of binary files and applying the reverse engineering techniques and tools to analyse any binary file without documentation.
II. Techniques to prevent binary file from reversing
III. Common vulnerabilities and protections in binary
IV. Static and dynamic malware analysis

Prerequisite:

OS fundamentals, Basics of Assembly language programming

Course Contents	
Unit I: **(16 Hrs; T1)** Introduction to reverse engineering; Low level software perspective; Windows OS fundamentals; Compilers, Execution Environments; Assembly language primer; Executable file formats; Calling Conventions; Offline code analysis; Reversing tools, Disassemblers, Debuggers, Decompilers, System monitoring tools;	CO1, CO2
Unit II: **(10 Hrs; T1)** Static or offline reversing of program binaries Dynamic reverse engineering; Debugging binary cod	CO2
Unit III : (12 Hrs; T2) Anti-reversing techniques, Breaking protections Reversing '.NET', De-compilation Software vulnerabilities – buffer overflow, integer overflow, vulnerabilities exploitation, mitigation; Return oriented programming;	CO2, CO3
Unit IV: (18 Hrs; T2) Introduction to malware Reversing malware – Static & Dynamic malware analysis techniques Packers & compression, Sandboxing executables& runtime analysis; Fileless Malware; Malware classification STUDENT PRESENTATION & INTERACTIVE SESSIONs	CO3, CO4
Lab Assignments	
1 To explore the components of executable file in Linux and Windows. (Unit-1)	
2 To Debug an executable to reverse DLL using Ollydbg and IDA Pro (Unit-1)	
3 Dll injection (Unit-2)	CO1
4 IAT extraction (Unit 1 & 2)	CO2
5 Usage of system monitoring tools (Unit 1,2,3,4)	CO3
6 Packing and analysis of executable files (Unit 3,4)	CO3
7 Find vulnerability in executable code (Unit 2,3)	CO2
8 Advanced Static Analysis of Malware samples (Unit 4)	CO3

9 Advanced Runtime Analysis of Malware samples (Unit 4) 10 To explore the components of executable file in Linux and Windows. (Unit 2,3) 11 Mini Project Statements: Hooking Detection, Keylogger Implementation and Detection, Heuristic rules for Malware Detection, Stack Smashing Attack / ROP Attack, Malware analysis & Report presentation (Unit 1,2,3,4)	CO3 CO4 CO4 CO2 CO1, CO2, CO3, CO4
Course Outcomes	
After completing this course, the students will be able to: **CO1:** Reverse engineer a binary executable file in an understandable form... **CO2:** Detect the vulnerabilities in the executable code **CO3:** Identify the different types of malware 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 Publcations, 2009. ISBN No – 978-0-387-09824-1 4. Erik Buchanan, Ryan Roemer, HovavShacham, and Stefan Savage. 2008. "When good instructions go bad: generalizing return-oriented programming to RISC."	

Course Code	Course Name	L – T – P	**Credits**
CS-613	**Security Standards & Penetration Testing**	3-0-2	**4**
Course Objective: This course examines the methods for securing information existing in different forms. This course will provide an introduction to the different technical and administrative aspects of Information Security and Assurance. Also, one cannot protect his information assets if he doesn't know how attackers think and what techniques attackers use to exploit systems. Hence, learning offensive security techniques like Ethical Hacking and penetration testing is becoming a need of future cyber security world. Objectives are: 1. To facilitate individual in gaining knowledge on information security management systems,.2. To facilitate individual in gaining knowledge on security standards like ISO-27001 standards, TCSEC, ITSEC, Secure coding etc. 3. To train individual to become competent information security			

professional by learning both theoretical as well as practical ethical hacking and penetration testing knowledge base **Prerequisite:** Basic computer networking, operating systems and computer programming knowledge is required.	
Course Contents **Unit I**: **(16 Hrs; T1)** Introduction to Information security, Concepts, Threats, Attacks, and Assets, Security Functional Requirements, Countermeasures , Access Control Principles, Access Rights , Discretionary Access Control, Role - Based Access Control, Mandatory Access Control , Trusted Computing and Multilevel Security, 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)	CO1,
Unit II: **(13 Hrs; T2,3)** 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, Penetration Testing Methodologies Security Assessments, Penetration Testing Methodologies, Penetration Testing Steps, Setting up own virtual ethical hacking lab for experimentation, Ethical Hacking and penetration Basics - Hacking terminology & attacks, Ethics, Legality.	CO3
Unit III : (12 Hrs; T2,3,4,5,6) Phases - Reconnaissance, Scanning,Gaining access, Maintaining access, Covering tracks; 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 Scansdetecting OS fingerprinting, banner grabbing, Null Sessions, SNMP/DHCP/DNS enumeration, Proxy Servers, Anonymizers, HTTP Tunneling Techniques, IP Spoofing Techniques; Cryptographic Techniques	CO2,
Unit IV: (10 Hrs; T4,6) Attacking System and Maintaining Access– Password/hashcracking, NetBIOS DoS Attacks, PasswordCracking Countermeasures; escalating privileges - exploiting vulnerabilities, Buffer Overflows,Rootkits, Hiding FilesNTFS Stream Countermeasures, Steganography Technologies, Cover tracks and Erase Evidence, Disabling Auditing, Clearing the event Log, Malware attacks-Trojan, Backdoor, Viruses, Worms, DoS/DDoS; Attacks, Windows Hacking; Linux Hacking; Web and Database Hacking; Google Hacking; Wireless Hacking; Mobile Hacking; Penetration Testing Tools like Kali Linux, Metasploit ,Pen-Test Deliverables **Lab Assignments** 1 Study Windows Essential Tools-Part 1 (Unit -1 02hours) 2 Study Windows Essential Tools-Part 2 (Unit -1 02hours)	CO2

3 Study Sysinternals utilities to manage, diagnose, troubleshoot, and monitor a Microsoft Windows environment (Unit -2 02hours) 4 Study passive information gathering tools. (Unit -3 02hours) 5 Write Security Policy Document (Unit -3 04hours) 6 Case study: LDRA and Parasoft tools (Unit -3 02hours) 7 Kali Linux Attacks – Part1 (Unit -3 02hours) 8 Kali Linux Attacks – Part2 (Unit -4 04hours) 9 SSPT Practice Test -1Quiz (Unit -4 04hours) 10 Apply data mining tools for cyber security related data analysis (Unit 02hours)	CO1,2,3, 4 CO1,3,4 CO2,3,4 CO1,3,4 CO1,4 CO2,3 CO3,4 CO2,3 CO2,4 CO1,2,3, 4

Course Outcomes

After completing this course, the students will be able to:
CO1: Students will able to identify and apply basic concepts, terminology, theories, models and methods in the field of information security management field. (PO1, PO3, PSO1).
CO2: Student will able to design policies for managing information security effectively adhering to ISO-27001 standards, TCSEC, ITSEC, Secure coding practices etc. (PO1,PO2, PO3, PSO1)
CO3: Student will learn to design, implement, integrate and manage various security countermeasures/tools/mechanisms/best practices and penetration testing through hands-on activities. (PO1, PO3, PSO1) attacks like Network Intrusion, DDOS, Malware attacks are carried out successfully by attackers. (PO1, PO2, PO3, PSO1, PSO2)
CO4: - End semester Exam

Text Books

3. Michael E Whitman, Herbert J Mattord, “Principles of Information Security”, Course Technology, 3rd Edition, 2008.
4. William Stallings and Lawrie Brown, “Computer Security: Principles and Practice”, 2nd edition, Pearson, 2012.
5. Krutz, R. L. & Vines, R. D., “The CISSP and CAP Prep Guide”, Platinum Edition, New York, Wiley Publishing., 2006.
6. Nina Godbole, “Information Systems Security: Security Management, Metrics, Frameworks and Best Practices”, Wiley India Pvt Ltd, 2012.
7. Dhavale, S. V. (2019). Constructing an Ethical Hacking Knowledge Base for Threat Awareness and Prevention (pp. 1-305). Hershey, PA: IGI Global.
8. 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 MatiAharoni, "Metasploitpentest guide",No starch Press, san Francisco, 2011
5. Bastian ballman, "Understanding n/w hacks:attack and defense with python", Springer,2012
6. Rich Annings, HimanshuDwivedi, Zane Lackey, "Hacking Exponsed Web 2.0", Tata Mcgraw hill Edition

Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/IBM/EC-Council sources

Digital	Course Name	L – T – P	**Credits**
CE695A	**Cyber Physical Systems**	3-0-2	**4**

Course Objective:

- 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 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).
- CPS combine cyber capabilities (computation and/or communication) with physical capabilities (motion or other physical processes). Cars, aircraft, and robots are prime examples, because they move physically in space in a way that is determined by discrete computerized control algorithms. Designing these algorithms to control CPSs is challenging due to their tight coupling with physical behavior. At the same time, it is vital that these algorithms be correct, since we rely on CPSs for safety-critical tasks like keeping aircraft from colliding, its role in Command & Control environments.
- To meet end-user, Administrator & System Designer perspectives, develop skill sets to be resourceful in knowledge & information systems. Enhance analytical capabilities to evaluate a domain specific and technical area. Multi-Disciplinary Course useful to any engineering discipline who are keen to contribute in digitization, like be it smart cities, smart telemedicine systems, automated and autonomous systems.

Course Contents	
Unit I: **(8 Hrs; T1, Ch-1)** CPS**:** Introduction Main Concepts, Challenges; Background role of Computer Networks, Data, Algorithms	CO1, CO2
Unit II: **(4 Hrs; T1, Ch-2, 3)** Self-organising Systems, Self-organisation in Natural Systems Inspiring Self-organising Software	CO1
Unit III: (6 Hrs; T1, Ch-4) Agents and Multi-Agent Systems Computing trends, Data device proliferation, Confluence of trends	CO1, CO2 CO3
Unit IV: (6 Hrs; T1, Ch-4,5) 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	CO3
Unit V: (6 Hrs; T1) Engineering Self-organising Systems, Middleware Infrastructures for Self-organising Pervasive Computing Systems	CO4
Unit VI: (6 Hrs) CPS design Standards, Time Models, CPS Special Interest Groups and Mitre Commendations in Design and developments	CO1, CO4
Unit VII: (6 Hrs) 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.	CO1, CO4
Lab Assignments 1 Describe the Use Case*. Model the case study. Abstract. (Unit-1 02 hours) 2 Modelling Tools exploration and implementation of the subsystems/ systems of the case study. (Unit-2hours)	CO1 CO2
3 Depiction of Agents in the designed model, and modelling their state, transitions and parameters status. Any one scenario for automous execution using algorithms. (Unit-3 & 4 02 hours)	C03
4 Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations. (Unit 4 & 5 02 hours)	CO3
5 Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations. Develop the methods to audit and parameters of importance. Generate the incidence response reports. (Unit 4 & 5 02 hours)	CO4 CO4

6 Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations. Specify the security concern and mitigation technique. Generate the incidence response reports. (Unit 6 02 hours)	
7 Create use case environment, implement & perform intra and Inter-system mappings. (Unit 6 02 hours)	CO4
8 Create model and implement any one security feature to demonstrate cyber security concern, intra and inter, and mitigation. Unit-7 02 hours	CO4
9 Study of Research paper on the assigned topic and its presentation. (Unit 1 to 7 Sem)	CO4
10 Mini-project. Implementation and Demonstration. Report Submission is essential (Unit 1 to 7 Sem)	CO4

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. (PO1, PO2, PO3, PSO1, PSO2)

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

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.

Course Code	Course Name	L – T – P	**Credits**
CE 70G	**Blockchain Technology**	3-0-2	**4**

Course Objective:
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

Prerequisite:
Expertise in Programming, Basic Knowledge of Computer Security, Cryptography, Networking.

Course Contents

Unit I:
Basic Cryptographic primitives used in Blockchain – Secure, Collison-resistant hash functions, digital signature, public key cryptosystems, zero-knowledge proof systems.

Unit II:
Basic Distributed System concepts – distributed consensus and atomic broadcast, Byzantine fault-tolerant consensus methods

Unit III:
Basic Blockchain – concepts to Bitcoin and contemporary proof-of-work based consensus mechanisms, operations of Bitcoin blockchain, crypto-currency as application of blockchain technology

Unit IV:
Ethereum Blockchain: Samrt Contract, Introduction to Solidity Language, Proof of stake, Ethereum Network

Unit V:
Hyperledger fabric platform- Decomposing the consensus process , Hyperledger fabric components, Chaincode Design and Implementation Hyperledger Fabric

Unit VI:
IoTA : Formation of Tangle, Cumulative weight, Consensus in IoTA, Double Spending Attack

Unit VII:
Beyond Cryptocurrency – applications of blockchain in cyber security, integrity of information, E-Governance and other contract enforcement mechanisms

Unit VIII:
Security and Research Aspects

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.

Course Code	Course Name	L – T – P	**Credits**
CE 66A	**Algorithmic Cryptanalysis**	3-0-2	**4**

Course Objective:

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.

Prerequisite:

Preferred if subjects related to cryptography and algorithms are studied in graduation or semester-I.

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) bruteforce, 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. 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**
CE606A	**Software Engineering program Modelling**	3-0-2	**4**
Course Objective: Major objective is to learn basic principles of Software Engineering and Design, which can facilitate the resource efficient model of the Software Systems **Prerequisite**: C programming and debugging concepts, basic concepts of operating systems			
Course Contents			
Unit I: Software Development Process, Planning software project, Cost, Scheduling and Risk Management. Metrices, Design Principles, Introduction to Object Oriented Design.			CO1, CO4
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 modeling			CO2, CO3
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			CO3, CO4

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.	CO1, CO4
Unit V: UML state diagrams and modeling -Operation contracts, Mapping design to code, UML deployment and component diagrams.	CO1, CO4
Lab Assignments Lab 1 UML Modelling UML modelling through Case study: Generation of Use-case diagram, class diagram, sequence diagram. Lab 2 Use Case Modelling Lab 3 Security Use Cases Modelling Lab 4 Identification of objects from Use Cases Lab 5 Object Modelling Lab 6 Activity Diagrams Lab 7 Sequence Diagrams Lab 8 Mapping of operations in Class and Sequence Diagrams Lab 9 Implementations of Design Patterns	

Course Outcomes

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

CO1: Students are able to understand Basic Principles of Software Engineering and Design

CO2: Students are able to create Use Cases and develop Use Case Models of the Systems.

CO3: Students are able to apply UML design notations to develop the software systems

CO4: Able to recognize and apply appropriate software design patterns for software efficiency

Text Books

1. Software Engineering- Pankaj Jalote, TMH
2. Software Engineering- Ian Sommerville, Pearson
3. 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, 2005.
2. 2. James W-Cooper, Addison-Wesley, "Java Design Patterns –A Tutorial", 2000.
3. 4. Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides, "Design patterns: Elements of Reusable object-oriented software", Addison-Wesley, 1995.

Course Code	Course Name	L – T – P	**Credits**
CE 681	**Mobile Computing**	3-0-2	**4**

Course Objective:
Course provides introduction to the fundamentals of mobile computing, mobile application development as well as wireless communication and security. Students will gain a sound understanding of the core concepts of mobile networks and the design of cellular networks including approaches to maximize the available capacity. The course will look at some current research in mobile computing security and wireless security. Students will learn android application development framework and use it to implement their assignments

Prerequisite:
Students are required to gain knowledge of basics of computer networking

Course Contents

Syllabus Description

Unit I
Principle of Cellular Communication, Overview 1G, 2G, 3G, 4G, LTE, 5G technologies. Wireless Transmission: Frequencies for radio transmission, Signals, Antennas, Signal Propagation, Multiplexing. Modulation, Spread spectrum, Cellular systems.

Unit II
Medium Access Control: Motivation for a specialized MAC, SDMA, FDMA, TDMA, CDMA, Comparison. GSM: Cellular Systems, Mobile Services, System Architecture, Radio Interface, Protocols, Localization and calling, Handover, Security. Data services: GPRS, HSCSD Mobility management: Handoff, Roaming Management, Handoff Detection Strategies, Channel Assignment, Radio Link transfer, GSM Location Update, Mobility Databases, Failure Restoration, VLR Overflow Control. Satellite Systems: GEO, LEO, MEO, Routing, Localization, Handover. Wireless LAN: Infrared and radio transmission, Infrastructure and Ad-hoc network, IEEE 802.11, Bluetooth.

Unit III
Mobile Device Platforms: Mobile OS, Palm Os, Win CE and Symbian. Mobile Network Layer: Mobile IP, Mobile Ad-hoc Networks, Cellular Digital Packet Data (CDPD), Wireless Local Loop (WLL) systems. Mobile Transport Layer: Traditional TCP, Classical TCP Improvements, Mobile-TCP. Wireless Application Protocol (WAP): WAP Architecture, Wireless Markup Language (WML), WML-Script, WAP 2.0.

Unit IV
Wireless Network Security: IEEE 802.11 Wireless LAN Attacks, Different Attack Tools, Different Types of Security Mechanisms, Wired Equivalent Privacy (WEP), Wi-Fi Protected Access (WPA), Wi-Fi Protected Access –II (WPA-2), Deploying Secure Wireless networks, Security in Bluetooth, Security in Adhoc Networks. Case Study: Android Application Development, Android Security.

Reference Books
1. Jochen Schiller, "Mobile Communication", 2nd Edition, Pearson Education. 2. Yi Bing Lin and ImrichChlamtac, "Wireless and Mobile Networks Architecture", John Wiley & sons, 2001. 3. Ed Burnette, "Hello Android", Pragmatic Bookshelf; Third Edition edition, 2010. 4. Yan Zhang, Jun Zheng, Miao Ma, ―Handbook of Research on Wireless Security‖, Volume 1, Idea Group Inc (IGI), 01-Jan-2008. 5. Raj Kamal, ―Mobile Computing‖, illustrated edition, Oxford University Press, Oxford higher education, 2007.

Course Code	Course Name	L – T – P	**Credits**
CE 683	**Information Warfare**	3-0-2	**4**

Course Objective:

This course will help students in gaining the knowledge of information warfare domain concepts including principles of information warfare (IW), Cyber warfare (CW), Offensive and defensive IW, military espionage, economic espionage, communications eavesdropping, computer break-ins, Open source intelligence, Covert Communication, Surveillance, ethical and legal concepts in the context of CW, Command and Control, Psyops and perception management. They will learn about different countermeasures, ethical hacking tools and techniques. They will form two teams (Red and Blue). One team carries out offensive operations against the; while other team will carry out defensive operations to protect the same information systems.

Prerequisite:

Students are required to gain knowledge of basics of computer networking

Course Contents

Syllabus Description

Unit I

Introduction to Information Warfare, Principles of Information Warfare, Conventional Warfare vs. Cyber Warfare, Information Warfare Elements (Information, Media, Computing Facilities, Communication Network, Operations, Warriors/Human Factors), Offensive and Defensive Information Warfare Operations,

Unit II

National Security Threats from State and Non-state Actors, Cyber-Terrorism, Information Warfare Policy, International Laws Governing Information Warfare, Law of War and Cyber Attack, Edward Snowden Revelations, ANT Catalogue, Supply Chain Risks, Open Sources, Open Source Intelligence (OSINT), Active Cyber Defenses, Competitive Intelligence, Piracy and Intellectual Property Rights,

Unit III

Watermarks, Steganography, Covert Communication, Privacy Protection, Subversion Techniques, Psyops and Perception Management, Military Deception, Espionage and Signals Intelligence, Insider Threat, Economic,

Corporate, and Military Espionage, Traffic Analysis, Packet Sniffing, Keystroke Monitoring, Environmental Surveillance, Computer Hacking and Cybercrime, Hacking Tools and Techniques, Attacks (Denial of Service, Spoofing, Masquerade, Identity Theft, Trojan Horses, Viruses, Worms, Fraud, Physical Destruction), **Unit IV** Security Measures (Anonymity, Sanitization, Trash Disposal, Shielding, Biometrics, Location based Authentication, Digital Signatures, Access controls, Surveillance), Communications Intercepts, Electronic Warfare, Command and Control, C4ISR, Network Centric Warfare, Wireless Security, Adhoc Network Mechanisms for Net Centric Operations, Information Warfare Case studies	
Text Books	
1. Wg Cdr MK Sharma, ―Cyber Warfare: The Power of Unseen‖, KW Publishers, New Delhi, 2011. 2. Emory A. Anderson, Cynthia E. Irvine, and Roger R. Schell, Roger R,.; ―Subversion as a Threat in Information Warfare‖, http://calhoun.nps.edu/bitstream/handle/10945/7123/04paper_subversion.pdf 3. Philip A. Myers, ―Subversion: The Neglected Aspect of Computer Security‖, Phd Thesis, Naval Postgraduate School, California, June 1980, http://csrc.nist.gov/publications/history/myer80.pdf 4. Dr. Roger R. Schell, ―Information Security: Science, Pseudoscience, and Flying Pigs‖, https://www.acsac.org/invited-essay/essays/2001-schell.pdf	

Course Code	Course Name	L – T – P	**Credits**
CE 689	**Fault-Tolerant Computing System**	3-0-2	**4**
Prerequisite: Students are required to gain knowledge of basics of computer networking			
Course Contents **Syllabus Description** 1. Introduction: Motivation, System view of high availability design, Terminology 2. Hardware redundancy: Basic approaches, Static & Dynamic, Voting, Fault tolerant interconnection network. Application: FTMP 3. Error detection techniques: Watchdog processors, Heartbeats, Consistency and capability checking, Data audits, Assertions, Control-flow checking Application: DHCP 4. Software fault tolerance: Process pairs, Robust data structures, N version programming, Recovery blocks, Replica consistency & reintegration, Multithreaded programs Application: HP Himalaya Servers			

5. Network fault tolerance: Reliable communication protocols, Agreement protocols, Database commit protocols Application: Distributed SQL server 6. Practical steps in design of high availability networked systemsApplication: Web services, Highly available clusters 7. Check pointing& Recovery Application: Microcheckpointing 8. Attack dimension to failures, byzantine generals problem, in context of side-channel attacks study fault induced leads to catastrophic failure 9. Case Studies	
Text Books	
1. Koren and C. Mani Krishna, Fault-tolerant Systems, 1st edition, 2007, Morgan Kaufmann. 2. D. P. Siewiorek and R. S. Swarz, Reliable Computer Systems - Design and Evaluation, 3rd edition, 1998, A.K. Peters, Limited. 3. D. K. Pradhan, ed., Fault Tolerant Computer System Design, 1st edition, 1996, Prentice-Hall.	

Course Code	Course Name	L – T – P	**Credits**
CE 690	**Parallel And Distributed Systems**	3-0-2	**4**
Course Objective: To meet end-user, Administrator & Designer perspectives. Enhance analytical capabilities to evaluate a system **Prerequisite**: CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations, Fundamental Computer architecture, programming environments, computer networks			
Course Contents **Syllabus Description** **Unit I:** Introduction to various Network Enabled Operations, Network Centric Operations, n-tier, P2P Systems; State of Art Examples and their types: GIS systems, MIS systems, Nature of Parallelism and Distributed Environment Models. **Unit II:** Parallel Architecture, Parallel Algorithms, Parallel Databases, Distributed Architecture, Distributed Systems, Distributed Databases **Unit III**: Systems modeling and Virtualization, Clusters for Scalable Parallel Computing, Virtual Machines, Virtualization Of Clusters **Unit IV:** Data Centers, Computing Clouds, Service-Oriented Architectures, Service-Oriented Architectures for Distributed Computing **Unit V:** Cloud Programming and Software Environment, Grids, P2P, Future Internet, Peer-To-Peer Computing and Overlay Networks, Ubiquitous Cloud and Internet of Things. Fog and Edge Computing.			

Unit VI: Adhoc Distributed & Self-Organising Environments, Pervasive and Ubiqutious Computations, Environments	

Text Books
1. Kai Hwang, Geoffrey C. Fox, and Jack J. Dongarra, ―*Distributed and Cloud Computing: From Parallel Processing to the Internet of Things*‖, MorganKaugmann Publications, 2012 2. Hwang, Kai, and Zhiwei Xu. *Scalable parallel computing: technology, architecture, programming*. McGraw-Hill, Inc., 1998.

Course Code	Course Name	L – T – P	**Credits**
CE 688	**Game Theory**	3-0-2	**4**
Course Objective: To understand the concepts of Game Theory and get an overview. To learn and appreciate the applications of game theory in Network Security **Prerequisite**: Basic understanding of Computer Networking and Network Security			
Course Contents **Syllabus Description** **Network Security Concepts**: Networks and Security Threats, Networks and World Wide Web, Security Threats, Attackers, Defenders, and their Motives, Attackers, Defenders, Defense Mechanisms, Security Tradeoffs and Risk Management, Security Tradeoffs, Security Risk Management, **Introduction to Game Theory**: What is Game Theory? Game Theory Classification, Introduction to Non-Cooperative Game Theory, General Formulation for Non-cooperative Games, Existence of Nash and Saddle-Point Equilibria in Finite Games, Existence and Uniqueness of Equilibria in Infinite Games, Prisoner‘s Dilemma, Co-operative Game Theory, Shapley Value, **Deterministic Security Games**: Security Game Model, Intrusion Detection Games, Matrix Games, Games with Dynamic Information, Sensitivity Analysis, 160 Modeling Malicious Behavior in Social Networks, Security Games for VehicularNetworks, Vehicular Network Model, Attack and Defense Model, Game Formulation and Numerical Analysis, Security Games in Wireless Networks, Random Access Security Games,Interference Limited Multiple Access Security Games, Revocation Games, Discussion and Further Reading, **Stochastic Security Games**: Markov Security Games, Markov Game Model,			

Solving Markov Games, Stochastic Intrusion Detection Game, Security of Interconnected Systems, Analysis of an Illustrative Example, Linear Influence Models, Malware Filter Placement Game, Stochastic Game Formulation, Simulations. **Decision Making for Network Security**, **Security Risk Management,** Quantitative Risk Management, Risk in Networked Systems and Organizations, A Probabilistic Risk Framework, Dynamic Risk Mitigation AndControl, Security Investment Games, Influence Network and Game Model, Equilibrium and Convergence Analysis, Incentives and Game Design, Cooperative Games for Security Risk Management, Coalitional Game Model, Coalition Formation under Ideal Cooperation **Resource Allocation for Security:** An Optimization Approach To Malware Filtering, Traffic Centrality Measures, Filtering Problem Formulations, A Robust Control Framework for Security Response, Network Traffic Filtering Model, Derivation of Optimal Controller and State Estimator, Optimal and Robust Epidemic Response, Epidemic Models, Feedback Response for Malware Removal, Multiple Networks, **Machine Learning for Intrusion and Anomaly Detection:** Intrusion and Anomaly Detection, Intrusion Detection and Prevention Systems, Open Problems and Challenges, Machine Learning for Security: An Overview, Overview of Machine Learning Methods, Open Problems and Challenges, Distributed Machine Learning, SVM Classification and Decomposition, Parallel Update Algorithms, Active Set Method and A Numerical Example, Behavioral Malware Detection.	

Text Books

1. T. Alpcan and T. Basar, ―Network Security: A decision and Game Theoritic Approach‖, Cambridge University Press.
2. M. Osborne, ―AN Introduction to Game Theory‖, Oxford University Press, 2003.

Reference Books:

1. Bragg et al, ― Network Security: The complete Reference‖, McGraw Hill Osborne, 2003.
2. B. Singh, ―Network Security and Management‖, Third Edition, PHI, 2013.
3. B.A. Forouzan and D. Mukhopdhyay, ―Cryptography and Network Security‖, 2nd Edition, McGraw Hill, 2010.
4. A. Dixit et al., ―Games of Strategy‖, Third Edition, W Norton Publishers, 2009.

Course Code	Course Name	L – T – P	**Credits**
CE 690	**Trustworthy Computing**	3-0-2	**4**

Course Objective:

Understanding of TPM capabilities, as well as other trusted computing standards and technologies

- Secure/Trusted/ Verified Boot
- Remote Attestation
- Use of open source tools for development of trusted process
- Be able to maintain and to develop trusted systems

Prerequisite:
Basic understanding of Boot Process, Shell Programming and Formal Methods, Fundamentals of OS.

Course Contents

Syllabus Description

Unit I
Introduction to trusted computing, Techniques for recording platforms state: Recording code identity, Recording dynamic properties.

Unit II
Use of platform information: Secure boot, Storage access control based on code identity. Information from platform states. Roots of trust: General-purpose tamper- resistant and Tamper-responding devices, General –purpose devices without dedicated physical defenses, Special-purpose minimal devices,

Unit III
Research solutions without hardware support. Challenges in bootstrapping trust in secure hardware: Problem definition, Potential solutions. Validating the process.

Unit IV
Implementing trust bootstrapping: Open-source tools. Human factors & usability, Limitations: Load-time versus run-time guarantees, Hardware attacks.

Text Books

1. Bryan ParnoJonathan M. McCune, Adrian Perrig, ―Bootstrapping trust in ModernComputers‖, Springer Briefs in ComputerScience.
2. D.Challener,K.Yoder,R.Catherman,D.Safford,andL.vanDoorn,―APracticalGuide toTrusted Computing‖, IBM Press, 2008.
3.DynamicsofaTrustedPlatform:ABuildingBlockApproach,DavidGrawrock,IntelPress;1stedition, SBN:1934053171

Course Code	Course Name	L – T – P	**Credits**
CE 692	**Computational Geometry and Applications**	3-0-2	**4**

Prerequisite:
The students are assumed to have a basic knowledge of the design and analysis of algorithms and data structures. No knowledge of the application domains is required, and hardly any knowledge of geometry. The analysis of the randomized algorithms requires very elementary knowledge of probability theory

Course Contents **Syllabus Description** **Unit I** Geometric primitives, Line intersection, randomized incremental concepts, **Unit II** Triangulation and visibility, Linear programming in two and three dimensions, **Unit III** Orthogonal range searching, Point location and Binary Space Partitions, **Unit IV** Voronoi diagrams and Delaunay triangulation, Convex hulls, Non-orthogonal range searching	

Text Books

1. *Computational Geometry: Algorithms and Applications*‖, Third Edition (March 2008), Mark de Berg, TU Eindhoven (the Netherlands), Otfried Cheong, KAIST (Korea), Marc van Kreveld, Mark Overmars, Utrecht University (the Netherlands), Springer-Verlag

Course Code	Course Name	L – T – P	**Credits**
CE 698	**Multimedia Security**	3-0-2	**4**

Course Objective:

1. To facilitate individual in gaining knowledge on digital watermarking, steganographic and encryption techniques on multimedia signals like image, audio and video for digital rights management applications.

2. To facilitate individual in gaining knowledge on forensics on multimedia signals like image, audio and video for multimedia tamper/forgery detection applications.

3. To teach biometric security concepts. Student will learn and implement various algorithms using MATLAB, Python during hands-on activities carried in the Laboratory.

Prerequisite:
Basic computer programming knowledge is required

Course Contents **Syllabus Description** Steganaography and Steganalysis; Information Hiding, Digital Watermarking – Basics of host Image/Video/Audio signals, Multimedia compression and decompression, Lossless compression, Models of watermarking, watermark detection by correlation; message coding, Mapping message in message vectors, Error correction coding, Detecting multi-symbol watermarks, Watermarking with side information, Informed embedding, Informed coding; Structured dirty-	

paper codes, Analyzing errors, Message errors, ROC curves, The effect of whitening on error rates, Analysis of normalized correlation, Using perceptual mode, Evaluating perceptual impact of watermarks; General forms of perceptual model, Perceptual adaptive watermarking, Robust watermarking, Spread Spectrum Watermarking, DCT-Domain Watermarking, A Buyer-Seller Watermarking Protocol, Text/Image/Video/Audio watermarking, Watermark security and cryptography, Content authentication, Applications: Digital Right Management Products & Laws, copyright protection; traitor tracing; tamper proofing; copy control; Signal processing attacks. Machine learning approaches in multimedia security, Intelligent Techniques for watermarking.

Multimedia Encryption, Image/audio/video Forensic and forgery detection, Biometric Security-Introduction to Biometrics, Fingerprint Recognition, Face Recognition, Iris Recognition, Hand Geometry Recognition, Gait Recognition, The Ear as a Biometric, Voice Biometrics, A Palm print Authentication System, Online Signature Verification; Introduction to Multi biometrics, Multi biometrics Using Face and Ear, The Law and the Use of Biometrics, Biometric System Security, Spoof Detection Schemes, Linkages between Biometrics and Forensic Science, Biometrics in the Government Sector, Biometrics in the Commercial Sector, Biometrics Standards, Biometrics databases

Text Books

1. Cox I., M. Miller, J. Bloom, J. Fridrich and T Kalker, "Digit Watermarking and Steganography", Second Edition, Morg Kaufmann Publishers, 2008.
2. Jain, Anil K.; Flynn, Patrick; Ross, Arun A. (Eds.), Handbook of Biometrics, Springer, 2008.
3. Borko Furht and Darko Kirovski, ―Multimedia Security Handbook‖, 2004 by CRC Press ISBN 9780849327735
4. Stefan Katzenbeisser. Fabien A. P. Petitcolas (Eds). ―Information Hiding Techniques for Steganography and Digital Watermarking.‖ Artech House Books

Reference Books:

1. Chun-Shien Lu, ―Multimedia Security: Steganography and Digital Watermarking Techniques for Protection of Intellectual Property‖, IDEA GROUP PUBLISHING, 2004

Course Code	Course Name	L – T – P	**Credits**
CE 695	**Cyber-Physical & Self-Organizing Systems**	3-0-2	**4**

Course Objective:

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). **Prerequisite**: CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations, Theoretical knowledge of Computer Science and Engineering

Course Contents **Syllabus Description** **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	

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

Course Code	Course Name	L – T – P	**Credits**
CE 69B	**Network Forensics**	3-0-2	**4**

Course Objective:

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

Prerequisite:

CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations, Theoretical knowledge of Computer Science and Engineering

Course Contents

Syllabus Description

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 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

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, 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**	3-0-2	**4**

Course Objective:
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.

Prerequisite:
Basic image processing knowledge/computer programming knowledge is required.

Course Contents

Syllabus Description

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

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. AndriesEngelbrecht (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**	3-0-2	**4**

Course Objective:

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

Prerequisite:

Basic image processing knowledge/computer programming knowledge is required.

Course Contents

Syllabus Description

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

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 3. Research papers and survey articles to be announced in class

Course Code	Course Name	L – T – P	**Credits**
CE 70B	**Advanced Algorithms**	3-0-2	**4**

Course Contents

Syllabus Description

Unit I: Basics

Data Structures, Abstract Data Types, Dictionaries, Parameters of Algorithms, Growth Functions, Asymptotic Notations & Complexity analysis, Complexity measures.

Unit II: Algorithms

Classic Algorithms, Purpose (S, S, SM, PF, Opti, Prob, Rand), Examples of each, Types of Algorithms, P Type, NP Type, Open Problems, Examples of Algorithms for Internet Search, Web Contents Organization and retrieval

Unit III: Soft-Computing Based Algorithms

Need, Modularity, Sequential, PRAM models, Classic Vs Soft Computing Algorithms, AI enabled Examples of Algorithms for Internet Search, Web Contents Organization and retrieval

Unit IV:Algorithms for AI & Special Applications: Classic Algorithms, Light-Weight Algorithms & Techniques, Self-Organization & Fault-Tolerance Techniques, Nature Inspired Algorithms

Unit V:Futuristic Trend: Computations in Cyber Physical Systems CPS, CPS based parallel & distributed Algorithms, Quantum Computing, Concepts of Qubits, Quantum Algorithms, Quantum Search-Space optimization

Text Books

1. T. H Cormen, C E Leiserson, R L Rivest and C Stein: Introduction to Algorithms, 2nd Edition, Prentice-Hall of India, 2009 (Latest Publication available during training)

Reference Books:

1. Ellis Horowitz, Sartaj Sahni, S.Rajasekharan: Fundamentals of Computer Algorithms, University Press, 2007. Kenneth A. Berman, Jerome L. Paul: Algorithms, Cengage Learning, 2002.
2. R.Sedgewick, ―Algorithms in C++ : Fundamentals, Data Structures, Sorting, Searching, Parts 1-4 (English) 3rd Edition, Pearson.

3. Recommended Research papers during instruction

Course Code	Course Name	L – T – P	**Credits**
CE 700	**Quantum Computing**	3-0-2	**4**

Course Objective:

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

Prerequisite:

are complex numbers and linear algebra

Course Contents

Syllabus Description

1. 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

2. Unit II: Mathematical Model of Quantum Computing, Qubit, Qubit Measurement, Systems with Multiple Qubits, Measuring the Multiple Qubits Systems, Quantum System Evolution & Computations

3. Unit III: Quantum Computer and Quantum Algorithms,Deutsch's Problem, Quantum Computer Prototype, Suitable Algorithms

4. Unit IV: Shor's Algorithm, Factoring and the RSA, Factoring and Period Finding, Quantum Fourier Transform

5. Unit V: Grover's Algorithm. A Quantum Computer Application Boundaries, Grover's Algorithm, Challenges

6. Unit VI: Quantum environments, Search Spaces, Search Optimisation, Storage Optimisation, Quantum Resources, Future, Challenges

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. 2. **References:** Research Papers as discussed in the class room.

Course Code	Course Name	L – T – P	**Credits**
CE 70D	**Computer Network Audit & Forensics**	3-0-2	**4**

Course Objective:
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

Prerequisite:
Preliminary knowledge Electronic Communications (Graduation Level), Computer Networks (Graduation Level) & IPV4, Networking Devices, Finite State Automata, Socket Programming, Algorithms

Course Contents

Syllabus Description

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 IV: 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 V: Futuristic Networks, Dependable Networks, AI-Enabled Network Environments, Network Virtualization, SDNs, Sensor Networks, IoT, Evolution in Computing Environments like Cloud, Edge, Fog, Ubiquitous, Pervasive

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, 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. 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 697	**Biometric Security**	3-0-2	**4**

Course Objective:

Biometrics has emerged as a specialized field in criminal forensics, public safety surveillance, user authentication and identification. Expansions of biometric modalities are ranged from fingerprint, face and other traits to multimodal biometric traits. Objectives of this course to introduce the student’s different modality based biometric identification systems, to help them to understand the difference between advanced biometric techniques with respect to traditional authentication mechanisms. Students after learning this course would be able to design and develop biometric systems by utilizing inter-disciplinary knowledge related to fields like Pattern Recognition, Image Processing and Machine Learning etc.

Prerequisite:

CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations, Theoretical knowledge of Computer Science and Engineering

Course Contents

Syllabus Description

1. Introduction: History of Biometrics, Multimodal Biometric Systems, Recent Advances

2. Authentication Technologies, Access Control

3. **Finger Print Biometrics**: Sensors, Dactyloscopy, Types, Algorithms

4. **Handwriting biometrics**: Static and Dynamic Recognition

5. **Iris Biometrics**: Retinal Scanning, Visible and Near Infra red Imaging, Operating Principle, Advantages and Shortcomings

6. **Voice Biometrics**: Verification versus Identification, Text Dependent and Text Independent, Technology, Applications

7. **Face Recognition**: Techniques for Face Acquisition/Recognition, Advantages and Disadvantages, History, Anti-facial recognition

8. **DNA finger printing/ Profiling**: Process, DNA Database, DNA evidence,

9. **Statistical Measures for Biometrics**:

10. **Biometric Devices**: Personal, Handheld, Biometric spoofing, Accuracy

Text Books

1. P. Reid, ―Biometrics for Network Security‖, Prentice Hall, 2014.
2. J. Chirrillo and S. Blaul, ―Implementing Biometric Security‖, Wiley, 2013.

Reference Book:

2. AK Jain, ―Introduction to Biometrics‖, Springer, 2011.
3. J. Ashborn, ―Biometrics: A Complete Guide‖, Springer, 2003

Course Code	Course Name	L – T – P	**Credits**
CE 70E	**Machine Learning in Python**	3-0-2	**4**

Course Objective:

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.

Prerequisite:

basics of probability & statistics is required

Course Contents	
Syllabus Description **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 V** Logistic Regression, Support Vector Machine, Kernel function and Kernel SVM. **UNIT VI** Neural network: Perceptron, multilayer network, backpropagation, introduction to deep neural networks. **UNIT VII** Clustering: k-means, Gaussian mixture model.	
Text Books	
1. Geron Aurelien, ―Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems‖, OReilly, 2017. 2. Jerome H. Friedman, Robert Tibshirani, and Trevor Hastie, ―The Elements of Statistical Learning‖, Springer, 2001. 3. Sebastian Raschka, ―Python Machine Learning‖, Packt, 1st Edition, 2015	

Course Code	Course Name	L – T – P	**Credits**
CE 70F	**Cloud Computing**	3-0-2	**4**
Course Objective: 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. **Prerequisite**: basics of probability & statistics is required			
Course Contents **Syllabus Description** **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 SimulatorWeek 8 : Research trend in Cloud Computing, Fog Computing **Lab Assignments**	
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. 3. OpenStack Cloud Computing Cookbook by Kevin Jackson	

Course Code	Course Name	L – T – P	**Credits**
CE 70H	**Cyber Security & Cryptography for Embedded Systems**	3-0-2	**4**
Course Objective: Developed the knowledge of security concepts, cyber-attacks and technologies to develop secure embedded systems. **Prerequisite**: Basic understanding of Number Theory, Fundamentals of Operating Systems and Knowledge of programming language.			
Course Contents **Syllabus Description** Introduction to Security, Introduction to Embedded Security. Vulnerability types, Taxonomy of Attacks, Defense Mechanisms, Mathematics of Cryptography, Basics of symmetric versus asymmetric key encryption. Early ciphers - Substitution, permutation and product ciphers. Block versus stream ciphers. Basics of entropy and perfect secrecy, Mathematical foundations of the 180 discrete logarithm problem, Diffie-Hellman Key Exchange, Mathematical foundations of RSA, Encryption using Elliptic curve The cryptographic hash – properties, Data Integrity, The cryptographic hash - construction, the Birthday paradox, Message Authentication, digital signature. Side Channels attacks on Embedded Systems, Embedded Cryptography, A5 Encryption for GSM, Hardware based Security. Transport layer security (TLS/SSL), FPGA based encryption and Decryption			
Text Books			
1. Hardware Security: Design, Threats and Safeguards‖ by Debdeep Mukhopadhyay and Rajat Subhra Chakrabarty, CRC Press,2015.			

2. Cryptography & Network Security‖ by William Stallings4th Edition, 2006, Pearson Education Asia.
3. Cryptography and Network Security‖ by Behrouz A. Forouzan, Mc Graw Hill.
4. Cryptography & Network Security‖ by Kahate A, Tata Mc Graw Hill, 2004.
5. Morrie Gasser: Building a Secure Computer System
6. Michael Ligh, Steven Adair, Malware Analysts's cookbook, Wiley publishing

Course Code	Course Name	L – T – P	**Credits**
CE 682	**Secure Software Engineering**	3-0-2	**4**

Course Objective:
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

Prerequisite:
C programming and debugging. Basic concept of Operating Systems.

Course Contents

Syllabus Description

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 are able to understand Basic Principles of Software Engineering and Design

CO2: Students are able to create Use Cases and develop Use Case Models of the Systems.

CO3: Students are able to apply UML design notations to develop the software systems

CO4: Able 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 5. Threat Modeling by Frank Swiderski, Window Snyder, Microsoft Press, ISBN-10:0735619913 6. Research Paper and Articles in Journals and Conference Proceedings.
Reference Books
1. Jochen Schiller, "Mobile Communication", 2nd Edition, Pearson Education. 2. Yi Bing Lin and ImrichChlamtac, "Wireless and Mobile Networks Architecture", John Wiley & sons, 2001. 3. Ed Burnette, "Hello Android", Pragmatic Bookshelf; Third Edition edition, 2010. 4. Yan Zhang, Jun Zheng, Miao Ma, ―Handbook of Research on Wireless Security‖, Volume 1, Idea Group Inc (IGI), 01-Jan-2008. 5. Raj Kamal, ―Mobile Computing‖, illustrated edition, Oxford University Press, Oxford higher education, 2007.

Course Code	Course Name	L – T – P	**Credits**
CE 69F	**Theory of Computation**	3-0-2	**4**
Course Objective: 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). **Prerequisite**: CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations, Theoretical knowledge of Computer Science and Engineering			

Course Contents

Syllabus Description

1.**Introduction**: Motivation , Terminology, History

2. **Computers and Science of Computing:** Computability, Undecidability, Intractability, and Intelligence

3. **Automata**: Construction, Finite Automata, Limitations of Finite Automata

4. **Non-Deterministic Finite Automata**, Moore Machine, Mealy Machine

5. **Regular Languages and Expressions**: Equivalence, Regular expressions in practice

6. **Grammars**: Parsing and Derivation, Grammar for regular languages, Converting Regular grammar to Automata

7. **Nature of Regular Languages:** Closure properties, Peigeonhole principle, Pumping Lemma, Adversarial Game

8. **Context Free Languages and Grammars**: Context Free Behaviour, CFGs, Ambiguity, Chomsky Normal Form, Simple, Linear and other grammars

9. **Pushdown Automata**: Stack Behviour, Constructing PDAs, CFGs to PDAs, CFL-CFG-PDA Triad

10. **Nature of Context Free Languages**: Closure properties

11. **Turing Machines**: Construction, Definition, Complex Turing Machines, Church Turing Thesis, Universal Turing Machines

12. **The Chomsky Hierarchy**: Languages, Grammars and Machines, Recursive Languages, Idea of Context

13. **Computability and Undecidability**: Halting Problem, P = NP?

Text Books

1. K. Mahesh, ―Theory of Computation: A problem solving approach‖, Wiley publishers. 2015

2. Hopcroft, Motwani & Ullman, ―Introduction to Automata Theory, Languages and Computation‖, 3rd Edition, Pearson, 2007.

Reference Book:

1. M. Sipser, ―Introduction to Theory of Computation‖, 3rd Edition, Wordsworth Publishing, 2012.

Course Code	Course Name	L – T – P	**Credits**
CE699	**Internet of Things**	3-0-2	**4**

Course Contents

Syllabus Description

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 IoTenablingTechnologies, 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 & Cloudofferings,Software environments, NEO, Security

Course Outcomes

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

CO1: Students are able to understand Basic Principles of Software Engineering and Design

CO2: Students are able to create Use Cases and develop Use Case Models of the Systems.

CO3: Students are able to apply UML design notations to develop the software systems

CO4: Able 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)
3. “Designing the internet of things”, McEwen, Adrian, and Hakim Cassimally. John Wiley& Sons, 2013.
4. Research Papers discussed in the classroom discussions

Reference Books

1. Jochen Schiller, "Mobile Communication", 2nd Edition, Pearson Education.
2. Yi Bing Lin and ImrichChlamtac, "Wireless and Mobile Networks Architecture", John Wiley & sons, 2001.

3. Ed Burnette, "Hello Android", Pragmatic Bookshelf; Third Edition edition, 2010.
4. Yan Zhang, Jun Zheng, Miao Ma, ―Handbook of Research on Wireless Security‖, Volume 1, Idea Group Inc (IGI), 01-Jan-2008.
5. Raj Kamal, ―Mobile Computing‖, illustrated edition, Oxford University Press, Oxford higher education, 2007.

Course Code	Course Name	L – T – P	**Credits**
CE691	**SECURE WIRELESS SENSOR NETWORKS**	3-0-2	**4**

Course Objective:
To meet End-User, Network-Administrator and Network-Designer perspectives

Prerequisite:
Computer Networks Fundamentals, Programming

Course Contents

Syllabus Description

Unit I: Introduction, WSN Resources & constraints, Relevance to IoTs, Relevance to Cyber-Physical Systems, Relevance to Network Centric Operations, Relevance to Data Stream Management Systems, Relevance to the increasing demand of high performance computations, SCADA, battle sensor.

Unit II: WSN Network Architecture, MAC Layer protocols, Naming and Addressing, Synchronization, Location & positioning, Topology control, Connected Dominating Sets, Routing Protocols, Data-Centric & Content-based networking, Data-Centric querying, WSNs versus IoTs

Unit III: Vulnerabilities, threats, attacks & safeguards in WSN, key distribution methods & protocols, multi-party computations inclusion, RF-Id communications, open source hardware concept, Security goals for WSNs, Attacks on WSNs: Passive & Active Attacks, Security Mechanisms, Security Models for WSNs, Challenges in WSNs: with respect to wireless medium, resource scarcity, ad-hoc deployments, hostile environments, immense scale, etc. Application oriented: Secure Wireless Networks.

Text Books

1. **FUNDAMENTALS OF WIRELESS SENSOR NETWORKS: THEORY AND PRACTICE, Authors: Waltenegus Dargie, Technical University of Dresden, Germany, Christian Poellabauer, University of Notre Dame, USA, Wiley, First Edition, 2010**

Reference Books

1. Ian F. Akykildiz, Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci, ―A Survey on Sensor Networks‖, IEEE Communication Magazine, year 2002.
2. Culler, D. E and Hong, W., ―Wireless Sensor Networks‖, Communication of the ACM, Vol. 47, No. 6, June 2004, pp. 30-33.
3. Adrian Perrig, John Stankovic, David Wagner, ―Security in Wireless Sensor Networks‖ Communications of the ACM, Page53-57, 2004
4. Chris Karlof, David Wagner, ―Secure Routing in Wireless Sensor Networks: Attacks and Countermeasures‖, AdHoc Networks (elsevier), Page: 299-302, year 2003
5. Al-Sakib Khan Pathan, Hyung-Woo Lee, Choong Seon Hong, ―Security in Wireless Sensor Networks: Issues and Challenges‖, International conference on Advanced Computing Technologies, Page1043-1045, year 2006
6. John Paul Walters, Zhengqiang Liang, Weisong Shi, Vipin Chaudhary, ―Wireless Sensor Network Security: A Survey‖, Security in Distributed, Grid and Pervasive Computing Yang Xiao (Eds), Page3-5, 10-15, year 2006
7. Pathan, A.S.K.; Hyung-Woo Lee; Choong Seon Hong, ―Security in wireless sensor networks: issues and challenges‖ Advanced Communication Technology (ICACT), Page(s):6, year 2006
8. Tahir Naeem, Kok-Keong Loo, Common Security Issues and Challenges in Wireless Sensor Networks and IEEE 802.11 Wireless Mesh Networks, International Journal of Digital Content Technology and its Applications, Page 89-90 Volume 3, Number 1, year 2009
9. Undercoffer, J., Avancha, S., Joshi, A. and Pinkston, J. ―Security for sensor networks‖. In Proceedings of the CADIP Research Symposium, University of Maryland, Baltimore County, USA, year 2002 http://www.cs.sfu.ca/~angiez/personal/paper/sensor-ids.pdf
10. Zia, T.; Zomaya, A., ―Security Issues in Wireless Sensor Networks‖, Systems and Networks Communications (ICSNC) Page(s):40 – 40, year 2006
11. Xiangqian Chen, Kia Makki, Kang Yen, and Niki Pissinou, Sensor Network Security: A Survey, IEEE Communications Surveys & Tutorials, vol. 11, no. 2,page(s): 52-62, year 2009
12. D. Djenouri, L. Khelladi, and N. Badache, ―A Survey of Security Issues in Mobile ad hoc and Sensor Networks,‖ IEEE Commun. Surveys Tutorials, vol. 7, pp. 2–28, year 2005.
13. S. Schmidt, H. Krahn, S. Fischer, and D. Watjen, ―A Security Architecture for Mobile Wireless Sensor Networks,‖ in Proc. 1st European Workshop Security Ad-Hoc Sensor Networks (ESAS), 2004.
14. Y. Wang, G. Attebury, and B. Ramamurthy, ―A Survey of Security Issues in Wireless Sensor Networks,‖ IEEE Commun. Surveys Tutorials, vol. 8, pp. 2–23, year 2006.
15. Yun Zhou, Yuguang Fang, Yanchao Zhang, Securing Wireless Sensor Networks: A Survey, IEEE Communications Surveys & Tutorials, year 2008
16. Xiuli Ren, Security Methods for Wireless Sensor Networks, Proceedings of the 2006 IEEE International Conference on Mechatronics and Automation , Page: 1925 ,year 2006
17. R.Roman, J. Zhou, and J. Lopez, ―On the security of wireless sensor networks,‖ in International Conference on Computational Science and Its Applications – ICCSA 2005, May 9-12 2005, vol. 3482 of Lecture Notes in Computer Science, (Singapore), pp. 681–690, Springer Verlag, Heidelberg, D-69121, Germany, 2005.
18. N. Sastry and D. Wagner, ―Security considerations for ieee 802.15.4 networks,‖ in Proceedings of the 2004 ACM workshop on Wireless security, pp. 32–42, Philadelphia, PA, USA: ACM Press, 2004.
19. WSN Security Models: Refer 4 papers: Paper 1: Wireless sensor network security model using zero knowledge protocol, ICC 2011; Paper 2. An energy efficient link-layer

security protocol for wireless sensor networks, EIT 2007; Paper 3. Toward resilient security in wireless sensor networks, MobiHoc 2005; Paper 4. TinySec: a link layer security architecture for wireless sensor networks, SenSys 2004.

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 athrust on defence related problems. The present programme is conceived to understand, assimilate & usethe 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 Minimum CPI of 6.5 or 60% of marks or first class in qualifying degree. Bachelor degree in Engineering/Technology or Equivalent in CS/IT/ECE/ETC/EE or in relevant Disciplines and a valid GATEScore.

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 Course of 4 credits is delivered by Course experts through the duration of 16 weeks approximately. It consists of 3 hrs of class room interaction and 2 hrs of lab sessions per week. The evaluations follow continuous assessment process that includes – 3 monthly evaluation exams (10 Marks each), internal assessment (20 Marks) and final examination (50 Marks). The lab focuses on practical exposure to the cyber security tools and techniques in form of mini projects and lab assignments. The 3rdand 4th semesters have a major component of MTech project dissertation, 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 MTech thesis is submitted and evaluated by the panel of expert examiners at the end of 4th semester.

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 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.

Semester I

Sr. No.	Course Code	Course	Contact Hours / Week		Credits
			L	T/P	
1	CE 601	Responsible Artificial Intelligence	3	1	4
3	CE 602	Intelligent Algorithms	3	1	4
4	CE 603	Deep Neural Networks	3	1	4
5	CE 604	Practical Machine Learning	3	1	4
6	CE 605	Mathematics for Machine Learning	3	1	4
7	AM 607	Mathematics for Engineers	3	1	4
8	PGC 601	Research Methodology and IPR	2	0	2
		Total	**20**	**6**	**26**

Semester II

Sr. No.	Course Code	Course	Contact Hours / Week		Credits
			L	T/P	
1	CE 611	Computer Vision	3	1	4
2	CE 612	Adversarial and Generative AI	3	1	4
3		Elective I (from Department)	3	1	4
4		Elective II (from Department)	3	1	4
5		Elective III	3	1	4
6		Elective IV	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	**20**	**6**	**26**

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	**T/P**	
1	CE 651	M.Tech. Dissertation Phase-I	28		14
		Total	**28**		**14**

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	**T/P**	
1	CE 652	M.Tech. Dissertation Phase-II	28		14
		Total	**28**		**14**

<u>List of Open Electives Semester-II</u>

Sr. No.	Course Code	Course
1.	CE- 613	Large Language Models
2.	CE-695A	Cyber Physical Systems
3.	CE-630	Virtual Reality
4.	CS-613	Security Standards and Penetration Testing
5.	CS-611	Digital Forensics
6.	CS-612	Reverse Engineering & Malware Analysis
7.	CE-70G	Blockchain Technology
8.	CE-66A	Algorithmic Cryptanalysis
9.	CE-699	Internet of Things
10	CE-633	Pattern Recognition
11	CE-691	Secure Wireless Sensor Networks
12	CE-606A	Software Engineering & System Modelling
13	CE-694	Big Data Analysis and Algorithms
14	• Open Electives	
• 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.		

SEMESTER I CORE COURSES

Course Code	Course Name	L – T – P	**Credits**
CE-601	**Responsible Artificial Intelligence**	3-0-2	**4**

Course Objective:
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

Prerequisite:
Statistics, any one Programming Language, Knowledge of the following will help: Data Storage and Retrieval Techniques, SQL, Algorithms. [These will be introduced, time-to-time during instructions as preliminaries]

Course Contents
Unit I: **(12 Hrs; T1)**
AI Fundamentals and Introduction to Responsible AI: Definition and scope of Artificial Intelligence, key concepts and terminology, overview of AI sub-fields (machine learning, natural language processing, LLMs), status of the technology, applications of AI across a range of domains and sectors, need of ethical and responsible AI, examples of AI/ML systems going wrong.

Unit II: **(12 Hrs; T2,3)**
Principles of Responsible AI: inclusive growth, sustainable development and well-being; human-centred values and fairness; transparency and explainability; robustness, security and safety; accountability. Problems with ML models - bias, robustness, generalization to OOD samples, adversarial examples, data protection; problems with generative models: hallucination, factual correctness, prompt injection, data leakage, deepf akes, copyright infringement, etc. Near- and long-term challenges of AI (misuse, misgeneralisation, rogue AGI), AI risks for Gen models, Adversarial attacks – text, images, NLP; examples will be drawn from various incidents.

Unit III : (12 Hrs; T2,3,4,5,6)
AI Fairness - sources of bias, exploratory data analysis, limitation of datasets; preprocessing, in-processing and post-processing to remove bias; group fairness and individual fairness, counterfactual fairness; fairness metrics, Fairness Score; fairness assessment tools and frameworks.

Robustness - dimensions of robustness: safety, reliability, resilience, causality; techniques for adversarial testing, robustness metrics, robustness assessment tools and frameworks

Unit IV: (10 Hrs; T4,6) Importance of AI incident reporting; role of standardisation organisations; comparison and critical analysis of current global AI policy and standards initiatives; overview and critical discussion of different codes of practices and principles for AI ethics and their implementation; critical discussion of methods for ethical impact assessment, Critical discussion of methods for ethical design, Interdisciplinary approaches to AI (relevant theories and methods from philosophical ethics, social sciences, and design studies); case study of the EU AI Act. **Lab Assignments** 1 Structured & Unstructured Data base generation and norms. Implementations. Platforms. Installations. Querying. 2 Bias Detection in Sentiment Analysis: Analyse sentiment datasets for biases against specific groups 3 Fair Classification: Implement and compare fairness-aware classifiers using different fairness constraints 4 Bias in Facial Recognition: Evaluate facial recognition systems for demographic biases. 5 Fairness Metrics Implementation: Calculate and compare different fairness metrics on a sample dataset 6 Impact of Pre-processing Techniques: Apply re-sampling techniques to mitigate bias and evaluate their effectiveness 7 Adversarial Debiasing: Implement an adversarial model to reduce bias in predictions. 8 Fair Representation Learning: Train models with fairness constraints and analyse learned representations 9 Bias in Recommendation Systems: Assess and mitigate bias in recommendation algorithms. 10 Policy Impact Analysis: Simulate the impact of different fairness policies on AI system outcomes 11 Ethical Decision-Making in AI: Design a decision-making system with ethical constraints and evaluate its fairness.	
Course Outcomes	
After completing this course, the students will be able to: **CO1:** Student will be able to identify and quantify biases using statistical/ mathematical techniques. **CO2:** Student will be able to evaluate and implement models to incorporate desired **CO3:** Student will be able to design and implement to incorporate fairness constraints **CO4:** Student will be able to create interpretable models and generate explanations for AI decisions.	
Text Books\ Reference Books	
1. Virginia Dignum, “Responsible Artificial Intelligence: How to Develop and Use AI in a Responsible Way” Springer Nature, 04-Nov-2019;ISBN-10 : 3030303705, ISBN-13 :	

978-3030303709

2. Voeneky S, Kellmeyer P, Mueller O, Burgard W, eds. In: The Cambridge Handbook of Responsible Artificial Intelligence: Interdisciplinary Perspectives. Cambridge Law Handbooks. Cambridge University Press; 2022:iii-iii.
3. Fairness Assessment and Rating of Artificial Intelligence Systems.(2023). https://tec.gov.in/pdf/SDs/TEC%20Standard%20for%20fairness%20assessment%20and%20rating%20of%20AI%20systems%20Final%20v5%202023_07_04.pdf
4. Agarwal, A., Agarwal, H. & Agarwal, N. Fairness Score and process standardization: framework for fairness certification in artificial intelligence systems. AI Ethics 3, 267–279 (2023) https://link.springer.com/article/10.1007/s43681-022-00147-7
5. Agarwal, A., Agarwal, H. A seven-layer model with checklists for standardising fairness assessment throughout the AI lifecycle. AI Ethics (2023) https://link.springer.com/article/10.1007/s43681-023-00266-9
6. EU Artificial Intelligence Act.(2024) https://artificialintelligenceact.eu/the-act/
7. OECD.(2019) https://oecd.ai/en/ai-principles
8. Jobin, A., Ienca, M. & Vayena, E. The global landscape of AI ethics guidelines. Nat Mach Intell 1, 389–399 (2019). https://doi.org/10.1038/s42256-019-0088-2
9. McGregor, S. (2021, May). Preventing repeated real world AI failures by cataloging incidents: The AI incident database. In Proceedings of the AAAI Conference on Artificial Intelligence (Vol. 35, No. 17, pp. 15458-15463).

Course Code	Course Name	L – T – P	**Credits**
CE-602	**Intelligent Algorithms**	3-0-2	**4**

Course Objective:

- To focus on the design of algorithms in various domains
- To provide a foundation for designing efficient algorithms.
- To provide familiarity with main thrusts of work in algorithms- sufficient to give some context for formulating and seeking known solutions to an algorithmic problem

Prerequisite:

C programming and debugging concepts, basic concepts of operating systems

Course Contents

Unit I: **(9 Hrs)**

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, FIFO Branch and Bound solution. Dynamic Programming

Module:2 Network Flow Flow Networks, Networks with multiple sources and sinks, Floyd-War shall algorithm, Max Flow and Min Cut, Ford-Fulkerson Method and Edmonds-Karp Algorithm, Bipartite Matching.

Unit II: **(12 Hrs)**
Module:3 Computational Complexity Class complexity classes: P, NP, Reductions, NP-completeness and NP-hard, NP-Complete Problems, CNF-SAT and 3SAT, Vertex-Cover and Clique

Module:4 Randomized Algorithms Las Vegas algorithms, Randomized Quick Sort, Monte Carlo algorithm, Primality Testing

Module:5 Approximation Algorithms Limits to Approximability, Bin Packing (First fit, Best fit),2 – Approximation algorithm for Metric TSP, Euclidean TSP, Max-SAT and Vertex Cover

Unit III : (10 Hrs)
Module:6 Computational Geometry Segment-intersection algorithm, Algorithms for finding convex hull: Graham's scan, Gift wrapping Algorithm. Finding the closest pair of points.

Module:7 Algorithms for AI Uninformed search, Heuristic search (8 queen and tiling problems), A* and AO* algorithms, Meta-Heuristics

Module 8 Generic Algorithms and Evolutionary Computation Introduction, Operators, Applications, GA, Fuzzy Logic

Unit IV: (10 Hrs; T4,6)
Module 9: Machine Learning Algorithms Supervised/Unsupervised, XGBoost, LGBM, Regression, Classification, Neural Networks

Module 10: Cryptographic Algorithms AES, DES, Hashing, Crypto-Currency Mining Algorithm, Block Chains, RSA, DHA Algorithms

Module 11: High Performance Multithreading, Parallel Processing, GPU, Linux Clusters, TPU

Lab Assignments
Lab 1 Crypto-Currency Mining
Lab 2 Insertion Sort and Merge Sort: Python Code
Lab 3 Merge Sort and Multi-Threading: Python Code
Lab 4 Random numbers and Linked List: Python Code
Lab 5 Dynamic Programming: Python Code
Lab 6 Decision Tree : Python Code
Lab 7 Graph Algorithms : Python Code
Lab 8 Stable Matching Algorithm: Python Code
Lab 9 Clustering Lloyd's Algorithm: Python Code

Lab 10 Genetic Algorithm: Python Code Lab 11 Fuzzy Logic: Python Code	

Course Outcomes

After completing this course, the students will be able to:
CO1: Familiarize students with different algorithmic techniques
CO2: Apply advanced methods of designing and analyzing algorithms.
CO3: Choose appropriate algorithms and use it for a specific problem
CO4: Understand different classes of problems concerning their computation difficulties
CO4: Implement algorithm, compare their performance characteristics, and estimate their potential effectiveness in applications

Text Books

1. Han Huang, Zhifeng Hao. "Intelligent Algorithms", 1st Edition, Elsevier, 2024.
2. Russel and Norvig, "Artificial Intelligence : A Modern Approach", 4th Ed, Pearson, 2022.
3. R. Hurbans, "Artificial Intelligence Algorithms", Manning Publishers, 1st Ed, 2020.

Reference Books

1. M.T.Goodrich and R.Tomassia, 'Algorithm Design: Foundations, Analysis and Internet examples' , John Wiley and sons, 2011.
2. T.H.Cormen, C.E.Leiserson, R.L.Rivest, and C.Stein, 'Introduction to algorithms',4th Edition, MIT Press, 2009.
3. A.Levitin, 'Introduction to the Design and Analysis of Algorithms', Third Edition, Pearson Education, 2012.

Course Code	Course Name	L – T – P	**Credits**
CE-603	**Deep Neural Networks**	3-0-2	**4**

Course Objective:
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

Prerequisite:
Knowledge of Statistical Techniques, Probability Theory, Data Structures and Algorithms, Programming Language such as Python, Matlab

Course Contents **Unit I**: **(5 Hrs; T1,R1)** **Introduction**: Overview of machine learning, linear classifiers, loss functions	CO1 , CO2

Optimization: Stochastic gradient descent and contemporary variants, backpropagation. **Unit II**: **(9 Hrs; T1,R1)** **Feedforward networks and training:** Activation functions, initialization, regularization, batch normalization, model selection, ensembles **Unit III : (16 Hrs; T1,R4)** Convolutional neural networks: Fundamentals, architectures, pooling, Visualization, Image Classification, and Object Detection using CNN **Unit IV: (10 Hrs; T2, R4)** Recurrent neural networks: Recurrent neural networks (RNN), long-short term memory (LSTM), language models, machine translation, image captioning, video processing, visual question answering, video processing, learning from descriptions, attention **Unit V: (10 Hrs; T2, R4)** Deep generative models: Auto-encoders, generative adversarial networks **Lab Assignments** Lab 1 Implementation of Linear Classifier using ML Unit 1 02 hours Lab 2 Implementation of Activation Functions and analyze the significance of Weight and Bias for ML Model Unit 2 02 hours Lab 3 Implementation of Perceptron Model for Binary Logic. Unit 2 02 hours Lab 4 Implementation of XOR using Multi-Layer Perceptron Unit 2 02 hours Lab 5 Implementation of Convolutional Neural Networks Unit 3 02 hours Lab 6 Object Detection using CNNs Unit 3 02 hours Lab 7 Image Classification Using CNNs Unit 3 2 Lab 8 Analyzing various CNN Architectures Unit 3 2 Lab 9 Implementing RNNs and LSTM Unit Lab 10 Analyzing CNNs and RNNs for Deep Learning Applications Unit 5	CO2 CO3 CO4 CO4 CO1,2 CO1,2 CO1,2 CO1,2 CO3 CO3 CO3 CO3 CO4 CO4

Course Outcomes

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

CO1: Remembering the basics of Neural Networks and Deep learning

CO2: Understanding the Different Neural Network Architectures and Deep Learning Methodologies

CO3: Applying different convolution operations, pooling, Functions, and sequence modeling

CO4: Analyze Various other Deep Learning architectures like RNN, Autoencoders and GANSs

Text 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/			
Reference Books			
1. K. P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012. 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.			

Course Code	Course Name	L – T – P	**Credits**
CE-604	**Practical Machine Learning**	3-0-2	**4**

Course Objective:

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

Prerequisite:

Knowledge of Statistical techniques, Linear algebra and computer programming knowledge is required.

Course Contents **Unit I**: **(12 Hrs; T1, 2)** 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, Supervised, unsupervised classification and regression analysis.	CO1
Unit II: **(12 Hrs; T2, 3)** 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	CO2
Unit III : (12 Hrs; T2, 3, 4) 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	CO2

Unit IV: (12 Hrs; T4, 5) 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, Case Study: Image spam detection	CO3
Lab Assignments	
1 Study and implement algorithms for data pre-processing and data cleaning Unit -1 02hours	CO1,3, 4
2 Study and implement algorithms for data feature selection reduction. Unit -1 02hour	CO1,3, 4
3 Study and Implement Linear Regression Algorithm for any standard dataset Unit -2 02hours	CO2,3, 4
4 Study and Implement unsupervised clustering Algorithms for any standard dataset Unit -3 02hours	CO1,3, 4
5 Study and Implement KNN for any standard dataset Unit -3 04hours	CO1,4
6 Study and Implement ANN for any standard dataset Unit -3 02hours	CO2,4
7 Study and Implement PCA for any standard dataset Unit -3 02hours	CO3,4
8 Case Study: Use of ML along with Fuzzy Logic/ GA/PSO/ACO to solve real world Problem Unit -4 04hours	CO2,3
9 Mini assignment: Apply ML to solve any real world problem Unit -4 04hours	CO2, 4
10 ML Practice Test – 1 Quiz Unit -1,2,3,4 02hours	CO1,2,3, 4

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. (PO1,PO2, PO3, PSO2)

CO2: Students will be able to understand various ML algorithms like and analyse their applications in real world (PO1,PO2, PO3, PSO2)

CO3: Students will be able to understand advanced ML algorithms and techniques etc. (PO1,PO2, PO3, PSO2)

CO4: Students will be capable of applying their ML knowledge and skills to solve engineering problems in various domains using ML programming languages(PO1, PO2, PO3, PSO1, PSO2)

Text 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.

Course Code	Course Name	L – T – P	**Credits**
CE-605	**Mathematics for Machine Learning**	3-0-2	**4**

Course Objective:
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

Prerequisite:
Machine Learning; Linear Algebra; Probability & Statistics, NLP.

Course Contents	
Unit I: **(12 Hrs; T1)** **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	CO1 ,CO2
Unit II: **(12 Hrs; T2)** **Probabilistic Machine Learning:** Fundamentals of Probability, Univariate and Multivariate Models, Joint Distributions, Basian Statistics and Regularization Methods, Decision and Information Theory.	CO2
Unit III: (12 Hrs; T2) **Optimizations:** Introduction to Optimization methods, first and second order optimization, Stochastic gradient descent, Constrained Optimization, Black box and derivative free optimization	CO3
Unit IV: (12 Hrs; T1) **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 Perspectiv	CO4

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
T1: "Mathematics for Machine Learning", By Marc Peter Deisenroth, A. Aldo Faisal, Soon, Cambridge University Press, 2020 **T2: "Probabilistic Machine Learning: An Introduction",** By Kevin P. Murphy, The MIT 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.

Course Code	Course Name	L – T – P	**Credits**
CE-611	**Computer Vision**	3-0-2	**4**
Course Objective: 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. **Prerequisite:** Statistical techniques, Linear algebra and computer programming knowledge is required.			
Course Contents **Unit I: (12 Hrs; T1)** Image processing foundations: Review of image processing techniques, classical filtering operations, thresholding techniques, edge detection techniques, mathematical morphology, texture analysis, Shapes and regions: Binary shape analysis – connectedness – object labeling and counting – size filtering – distance functions – skeletons and thinning			CO1
Unit II: (12 Hrs; T2) Corner and interest point detection, deformable shape analysis – boundary tracking, procedures – active contours – shape models and shape recognition – centroidal profiles – handling occlusion – boundary length measures – boundary			CO2

descriptors – chain codes, Fourier descriptors – region descriptors – moments, Hough transform: Line detection – Hough Transform (HT) for line detection – foot-of-normal method – line localization – line fitting **Unit III: (12 Hrs; T2, 3)** Case study: spatial matched filtering – GHT for ellipse detection – object location – GHT for feature collation RANSAC for straight line detection – HT based circular object detection – accurate center location – speed problem – ellipse detection **Unit IV: (12 Hrs; T4)** 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, Concepts of stereo vision **Lab Assignments** 1 Introduction to Digital Image Processing using python (Unit -1 02 hours) 2 Study and Implement Image Transformation Techniques (Unit -1 02 hours) 3 Study and Implement Image Transformation Techniques (Unit -1 02hours) 4 Study and Implement Edge Detection Techniques (Unit -1 02 hours) 5 Study and Implement Image Thresholding Transform (Unit -1 04 hours) 6 Study and Implement Morphological Operations (Unit -2 02 hours) 7 Study and Implement Harris Corner Point Detection (Unit-2 02hours) 8 Study and Implement SIFT (Unit -3 04hours) 9 Mini assignment: Apply CV techniques to solve any real world problem/ Presentations (Unit -4 02 hours) 10 CV Practice Test -1 Quiz/ Presentations (Unit -4 02 hours)	 CO3 CO3 CO1,2,3,4 CO1, 3,4 CO2,3,4 CO1,3,4 CO1, 4 CO2, 3 CO3, 4 CO2, 3 CO2, 4 CO1,2,3,4,
Course Outcomes	
After completing this course, the students will be able to: **CO1:** Students will be able to understand and apply image processing techniques including filtering operations, thresholding techniques, edge detection techniques etc. (PO1, PO2, PO3, PSO2) **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. (PO1, PO2, PO3, PSO2) **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. (PO1, PO2, PO3, PSO2) **CO4:** Students will be capable of applying their knowledge and skills to solve engineering problems in computer vision related domain. (PO1, PO2, PO3, PSO2)	
Text Books	
1. E. R. Davies, "Computer & Machine Vision", Fourth Edition, Academic Press, 2012. 2. R. Szeliski, "Computer Vision: Algorithms and Applications", Springer 2011. 3. Simon J. D. Prince, "Computer Vision: Models, Learning, and Inference", Cambridge University Press, 2012.	

4. Mark Nixon and Alberto S. Aquado, "Feature Extraction & Image Processing for Computer Vision", Third Edition, Academic Press, 2012.
Reference Books
1. D. L. Baggio et al., "Mastering OpenCV with Practical Computer Vision Projects", Packt Publishing, 2012. 2. Jan Erik Solem, "Programming Computer Vision with Python: Tools and algorithms for analyzing images", O'Reilly Media, 2012. 3. Sunita Vikrant Dhavale, "Advanced Image-based Spam Detection and Filtering Techniques", IGI Global, 2017 4. 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**
CE-612	**Adversarial and Generative AI**	3-0-2	**4**
Course Objective: To understand the concepts and needs of Generative modelling and Learn the concepts of probability and modelling. To implement the learned concepts to generate the data related to specific applications of image and Video. **Prerequisite:** Machine Learning; Multivariable Calculus; Linear Algebra; Probability & Statistics.			

Course Contents	
Unit I: **(10 Hrs; T1, R1)** 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.	CO1, CO2
Unit II: **(8 Hrs; T1, R1)** Autoencoders: Basics of autoencoders, Variational autoencoders (VAEs), Autoencoder-based	
Unit III: (14 Hrs; T2, R4) Deep Generative Models: Introduction to deep generative models, Deep Boltzmann Machines (DBMs), DeepBelief Networks (DBNs), Adversarial attacks on generative models, Neural Ordinary Differential Equations (ODEs)	CO3
Unit IV: (12 Hrs; T4) Applications of GANs for Image Generation, Super-resolution and Video Prediction	CO4
Lab Assignments	
1 Implementation of Discriminator using various CNN Models (Unit -1 024 hours)	CO3
2 Implementation of Generators using Variational Auto Encoders and Attention Models (Unit -2 04 hours)	CO3
3 Implementation of GANs using Up-sampling and Down-Sampling (Unit -3 04hours)	CO4
4 Case Studies on Radar Image Generation, Astronomical Image Generation, Activity Prediction (Unit -4 04 hours)	CO4

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
CO3: Applying different GAN architectures for Image and Video Data
CO4: Analyze Various GAN architectures for different applications

Text Books

1. Ian Goodfellow, Y. Bengio, A. Courville, Deep Learning, MIT Press, 2016. http://www. deeplearningbook.org.

Reference Books

2. Probabilistic Graphical Models, 2009, D. Koller, and N. Friedman, MIT Press.
3. A National Initiative on AI Skilling and Research (leadingindia.ai)
4. NPTEL Course Lecture Material: Deep Learning Part-II By Dr. Mitesh Kapra, IIT Chennai.

SEMESTER II ELECTIVE COURSES

Course Code	Course Name	L – T – P	**Credits**
CE-613	**Large Language Models**	3-0-2	**4**

Course Objective:
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.

Prerequisite:
Machine Learning; Linear Algebra; Probability & Statistics, NLP

Course Contents	
Syllabus Description	
Unit I (10 Hrs.; T3) Introduction, 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	CO1
Unit II: (8 Hrs.; T1) 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	CO2
Unit III: **(10 Hrs.; T1)** **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.	CO2
Unit IV: **(10 Hrs.; T2)** **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	CO3 CO4
Unit V: **(10 Hrs.; T2)** **Security:** Instruction tuning and RLHF	

Harms & Ethics, Security & Adversarial examples, Prompt injections, Data poisoning, backdoors and model stealing, Privacy in ML, Memorization + Differential Privacy, Data lifecycle, Explainability, Interpretability, AI Safety	

Course Outcomes
After completing this course, the students will be able to: **CO1**: Remembering the Probabilistic theory of LLMs **CO2**: Understanding Modeling Foundations and Neural Network Models for LLMs. **CO3**: Applying Transfer Learning for Training, Fine Tuning and Inference of LLMs **CO4**: Analyze LLMs for Security & AI Safety
Text Books
Large Language Models, Spring 2023 | Rycolab T1: LLM Course Notes Part 1 T2: LLM Course Notes Part 2 T3: S.Bird, E Klein and E Loper, ―Natural Language Processing with Python‖, O'Reilly, 20
Reference Books
R1: Deep Learning (deeplearningbook.org) R2: Introduction to Natural Language Processing (Eisenstein) R3: COS 597G: Understanding Large Language Models (princeton.edu)

Course Code	Course Name	L – T – P	**Credits**
CE630	**Virtual Reality**	3-0-2	**4**

Course Objective:

Understanding basic issues, concepts, principles and mechanisms in Virtual Reality.

- Definition of VR
- Applications of VR
- VR/AR/MR
- Hardware/Software
- Human Physiology and Perception
- Light and Optics
- Human Physiology of Vision
- Visual Perception, Visual Rendering
- Motion in Real and Virtual Worlds
- Tracking and Interaction
- Audio,

- Evaluating VR Systems

Current trends in VR

Prerequisite:

Basic Operating systems and Computer Programming, Computer Graphics knowledge is required.

Course Contents	
Unit-I	CO1,2
Introduction, Definition, Applications	CO1,2
Unit-II	
Bird’s Eye View, Hardware, Software, Human Physiology and Perception	CO1,2
Unit-III	CO1,2
Geometry of Virtual Worlds, Geometric models, Viewing Transformations, Chaining Transformations	
	CO1,2
Unit-IV	
Light and Optics, Lenses, optical aberrations, Human Eye, Cameras, displays	CO1,2,3
Unit-V	
Physiology of Human Vision: Cornea, Photoreceptors, Eye Movements, Implications for VR	CO1,2
Unit-VI	
Visual Perception: Perception of Depth, Perception of Motion, Perception of Color, Combining sources of information	CO1,2
Unit-VII	CO1,2
Visual Rendering: Ray tracing and Shading models, Rasterization, Correcting optical distortions, Improving latency and frame rates, Immersive photos and videos	CO1,2,3
Unit-VIII	CO1,2
Motion in Real and Virtual Worlds: Velocities and accelerations, Vestibular system, Physics in virtual world, Mismatched motion and vection	CO4
Unit-IX	
Tracking: Tracking in 2D, Tracking in 3D, Tracking position and orientation, Tracking attached bodies, 3D scanning of environment	CO2

Unit-X

Interaction: Motor programming and remapping, Locomotion and manipulation, social interaction and other interaction mechanisms

Unit-XI

Audio: Physics and sound, physiology of human hearing, Auditory perception, Auditory hearing

Unit-XII

Evaluation of VR Systems and Experiences: Perceptual training, recommendation for developers, Comfort and VR Sickness, Experiments on Human Subjects

Unit-XIII

Frontiers: Touch and Proprioception, Smell and taste, Robotic interfaces and Brain-machine interfaces

LAB Assignments:

1 Introduction to Unity 3D Install Unity 3d and learn hands-on various features and functionalities (Unit 1 2)
2 Virtual Reality App development using Unity3d Develop a sample VR application and install it on target device for viewing (Unit 1-4 2)
3 Augmented Reality App development using Unity3d and Vuforia Develop a sample AR app and install it on target device for testing (Unit 1-4 2)
4 AR App using Python, OpenCV and ARuco marker Develop and Test python and OpenCV app to use ARUCO marker (Unit 10, 12 2)
5 Virtual Tour app development and testing Develop a VR Tour app and test it on target devi (Unit 6,7 2)
6 Points Cloud generation using Matterport for VR Collect and install the images in Matterport to generate Point for testing (Unit 8 2)
7 VR App: Case Study Industry standard VR app is installed, tested and explored (Unit 1-12 2)
8 AR App: Case Study Industry standard AR App is installed, tested and explored (Units 1-12 2)
9 Advanced VR App development using Unreal Engine/Unity 3d An advanced app which involves scripting in C++/C# is developed using UnrealEnging or Unity3d (Units 1-12 2)
10 Advanced AR App development using AR Tool kit Develop and test the AR App (Units 1-12 2)

Course Outcomes

After completing this course, the students will be able to:
CO1: Students will be able to understand and apply Virtual Reality Concepts along with various applications. (PO1, PO3, PSO1)

CO2: Students will be able to understand and apply Virtual Reality concepts, hardware, software, standards and policies required for various applications. (PO1,PO2, PO3, PSO1) **CO3**: Students will be able to understand the importance of implementation of Virtual Reality Systems, Applications with Benefits and limitations(PO1, PO3, PSO1) **CO4**: Students will be capable of applying their knowledge and skills to solve engineering problems in Virtual Reality. (PO1, PO2, PO3, PSO1, PSO2)
Text Books
1. Steven Lavalle, "Virtual Reality", Cambridge Univerisity Press, (lavalle.pl/vr/book.html), 2020
Reference Books
1. Sherman W.R. and A B Craig, "Understanding Virtual Reality- Interface Application, and Design", Morgan Kaufmann, 2002. 2. Burdea G C and P Coffet, "Virtual Reality Technology", Second Edition, Wiley-IEEE presss, 2006.

Course Code	Course Name	L – T – P	**Credits**
CE695A	**Cyber Physical Systems**	3-0-2	**4**

Course Objective:

- 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 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).
- CPS combine cyber capabilities (computation and/or communication) with physical capabilities (motion or other physical processes). Cars, aircraft, and robots are prime examples, because they move physically in space in a way that is determined by

discrete computerized control algorithms. Designing these algorithms to control CPSs is challenging due to their tight coupling with physical behavior. At the same time, it is vital that these algorithms be correct, since we rely on CPSs for safety-critical tasks like keeping aircraft from colliding, its role in Command & Control environments.

- To meet end-user, Administrator & System Designer perspectives, develop skill sets to be resourceful in knowledge & information systems. Enhance analytical capabilities to evaluate a domain specific and technical area. Multi-Disciplinary Course useful to any engineering discipline who are keen to contribute in digitization, like be it smart cities, smart telemedicine systems, automated and autonomous systems.

Course Contents	
Unit I: **(8 Hrs; T1, Ch-1)** CPS**:** Introduction Main Concepts, Challenges; Background role of Computer Networks, Data, Algorithms	CO1, CO2
Unit II: **(4 Hrs; T1, Ch-2, 3)** Self-organising Systems, Self-organisation in Natural Systems Inspiring Self-organising Software	CO1
Unit III: (6 Hrs; T1, Ch-4) Agents and Multi-Agent Systems Computing trends, Data device proliferation, Confluence of trends	CO1, CO2
Unit IV: (6 Hrs; T1, Ch-4,5) 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	CO3
Unit V: (6 Hrs; T1) Engineering Self-organising Systems, Middleware Infrastructures for Self-organising Pervasive Computing Systems	CO3
Unit VI: (6 Hrs) CPS design Standards, Time Models, CPS Special Interest Groups and Mitre Commendations in Design and developments	CO4
Unit VII: (6 Hrs) 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.	CO1, CO4
Lab Assignments 1 Describe the Use Case*. Model the case study. Abstract. (Unit-1 02 hours) 2 Modelling Tools exploration and implementation of the subsystems/ systems of the case study. (Unit-2hours)	CO1 CO2

3 Depiction of Agents in the designed model, and modelling their state, transitions and parameters status. Any one scenario for automous execution using algorithms. (Unit-3 & 4 02 hours)	C03
4 Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations. (Unit 4 & 5 02 hours)	CO3
5 Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations. Develop the methods to audit and parameters of importance. Generate the incidence response reports. (Unit 4 & 5 02 hours)	CO4
6 Implement and apply Multi-Agent Systems. Enumerate the challenges, risks and mitigations. Specify the security concern and mitigation technique. Generate the incidence response reports. (Unit 6 02 hours)	CO4
7 Create use case environment, implement & perform intra and Inter-system mappings. (Unit 6 02 hours)	
8 Create model and implement any one security feature to demonstrate cyber security concern, intra and inter, and mitigation. (Unit-7 02 hours)	CO4
9 Study of Research paper on the assigned topic and its presentation. (Unit 1 to 7 Sem)	CO4
10 Mini-project. Implementation and Demonstration. Report Submission is essential (Unit 1 to 7 Sem)	CO4
	CO4

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. (PO1, PO2, PO3, PSO1, PSO2)

Text Books

2. 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

Reference Books

4. “Principles of Cyber-Physical Systems” - Rajeev Alur, MIT Press, 2015

5. Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006

6. Kurose and Ross, Top Down Approach of Computer Networks, Prentice Hall, 8th Edition 2021.

Course Code	Course Name	L – T – P	**Credits**
CS-611	**Digital Forensics**	3-0-2	**4**

Prerequisite:

Knowledge of OS, Assembly Languages like Python, Number System and their Conversions, Internal Structure of CD/DVD

Course Contents	
Unit I: **(12 Hrs; T1)** 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	CO1, CO4
Unit II: **(12 Hrs; T3)** Forensic study of database and their metadata, database contents, log-files for creating timeline or recover relevant information	CO3, CO4
Unit III : (12 Hrs; T2) MFT & Registry Hives Extraction from Windows OS through Tools and ScriptsData 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	CO2, CO4
Unit IV: (12 Hrs; T2) 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	CO2, CO4
Lab Assignments	
1.Perform Imaging and Analysis of Non-Volatile Memory using Open Source Tools in the absence of Write-Blockers. (UnitI 02Hrs)	CO1, CO4
2.Perform Imaging and Analysis of Non-Volatile Memory using EnCase/Other Open Source Tools With and Without Write Blockers. (UnitI 02Hr)	CO1, CO4
3.Explore the Phases of Ethical Hacking in terms of implementing some attack. (UnitI 02Hr)	CO1, CO4
4.Perform Imaging and Analysis of Volatile Memory using EnCase/Other Open Source Tools (UnitI 02Hr)	CO1, CO4
5.MFT & Registry Hives Extraction from Windows OS through Tools and Scripts. (UnitII 02Hr)	CO3, CO4
6.Recovering Deleted File from the File System (UnitII 02Hr)	CO3, CO4
7.SystemHiding Data into Slack Space. (UnitII 02Hr)	

8.Data Recovery and Secure deletion on Storage media. (UnitIII 02Hr) 9.Data Carving Using Open Source Tools (UnitIII 02Hr) 10.Information gathering and network traffic analysis using TCP DUMP and WIN DUMP (UnitIII 02Hr)	CO3, CO4 CO2, CO4 CO2, CO4 CO2, CO4
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. Marshell, 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 3. Pavan Duggal, "Cyberlaw–The Indian Perspective", 2009 Edition	

Course Code	Course Name	L – T – P	**Credits**
CS-612	**Reverse Engineering & Malware Analysis**	3-0-2	**4**
Course Objective: The course introduces reverse engineering techniques and further examines the use of reversing for detecting, analyzing, and eradicating malware. It involves: . Learning low level details of binary files and applying the reverse engineering techniques and tools to analyse any binary file without documentation.			

I. Techniques to prevent binary file from reversing

II. Common vulnerabilities and protections in binary

I. Static and dynamic malware analysis

Prerequisite:

OS fundamentals, Basics of Assembly language programming

Course Contents **Unit I**: **(16 Hrs; T1)** Introduction to reverse engineering; Low level software perspective; Windows OS fundamentals; Compilers, Execution Environments; Assembly language primer; Executable file formats; Calling Conventions; Offline code analysis; Reversing tools, Disassemblers, Debuggers, Decompilers, System monitoring tools;	CO1, CO2
Unit II: **(10 Hrs; T1)** Static or offline reversing of program binaries Dynamic reverse engineering; Debugging binary cod	CO2
Unit III : (12 Hrs; T2) Anti-reversing techniques, Breaking protections Reversing '.NET', De-compilation Software vulnerabilities – buffer overflow, integer overflow, vulnerabilities exploitation, mitigation; Return oriented programming;	CO2, CO3
Unit IV: (18 Hrs; T2) Introduction to malware Reversing malware – Static & Dynamic malware analysis techniques Packers & compression, Sandboxing executables& runtime analysis; Fileless Malware; Malware classification STUDENT PRESENTATION & INTERACTIVE SESSIONs	CO3, CO4
Lab Assignments 1 To explore the components of executable file in Linux and Windows. (Unit-1) 2 To Debug an executable to reverse DLL using Ollydbg and IDA Pro(Unit-1) 3 Dll injection (Unit-2) 4 IAT extraction (Unit 1 & 2) 5 Usage of system monitoring tools (Unit 1,2,3,4) 6 Packing and analysis of executable files (Unit 3,4) 7 Find vulnerability in executable code (Unit 2,3) 8 Advanced Static Analysis of Malware samples (Unit 4) 9 Advanced Runtime Analysis of Malware samples (Unit 4) 10 To explore the components of executable file in Linux and Windows. Unit 2,3 11 Mini Project Statements: Hooking Detection, Keylogger Implementation and Detection, Heuristic rules for Malware Detection, Stack Smashing Attack / ROP Attack, Malware analysis & Report presentation (Unit 1,2,3,4)	CO1 CO2 CO3 CO3 CO2 CO3 CO3 CO4 CO4 CO2 CO1, CO2, CO3, CO4

Course Outcomes
After completing this course, the students will be able to: **CO1:** Reverse engineer a binary executable file in an understandable form... **CO2:** Detect the vulnerabilities in the executable code **CO3:** Identify the different types of malware 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 Publcations, 2009. ISBN No – 978-0-387-09824-1 4. Erik Buchanan, Ryan Roemer, HovavShacham, and Stefan Savage. 2008. "When good instructions go bad: generalizing return-oriented programming to RISC."

Course Code	Course Name	L – T – P	**Credits**
CE 70G	**Blockchain Technology**	3-0-2	**4**

Course Objective:

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

Prerequisite:

Expertise in Programming, Basic Knowledge of Computer Security, Cryptography, Networking.

Course Contents

Unit I:

Basic Cryptographic primitives used in Blockchain – Secure, Collison-resistant hash functions, digital signature, public key cryptosystems, zero-knowledge proof systems.

Unit II:

Basic Distributed System concepts – distributed consensus and atomic broadcast, Byzantine fault-tolerant consensus methods

Unit III:

Basic Blockchain – concepts to Bitcoin and contemporary proof-of-work based consensus mechanisms, operations of Bitcoin blockchain, crypto-currency as application of blockchain technology

Unit IV:

Ethereum Blockchain: Samrt Contract, Introduction to Solidity Language, Proof of stake, Ethereum Network

Unit V:

Hyperledger fabric platform- Decomposing the consensus process , Hyperledger fabric components, Chaincode Design and Implementation Hyperledger Fabric

Unit VI:

IoTA : Formation of Tangle, Cumulative weight, Consensus in IoTA, Double Spending Attack

Unit VII:

Beyond Cryptocurrency – applications of blockchain in cyber security, integrity of information, E-Governance and other contract enforcement mechanisms

Unit VIII:

Security and Research Aspects

Reference Books

4. Bitcoin and Cryptocurrency Technologies by Arvind Narayanan, Joseph Bonneau, Edward Felten, Andrew Miller, Steven Goldfeder, Princeton University Press
5. "S. Shukla, M. Dhawan, S. Sharma, S. Venkatesan, 'Blockchain Technology: Cryptocurrency and Applications', Oxford University Press.
6. 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**	3-0-2	**4**

Course Objective:
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.

Prerequisite:
Preferred if subjects related to cryptography and algorithms are studied in graduation or semester-I.

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) bruteforce, 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

3. **Joux, A. (2009). Algorithmic Cryptanalysis (1st ed.). Chapman and Hall/CRC. https://doi.org/10.1201/9781420070033**
4. Mihailescu, Marius Iulian, and Stefania Loredana Nita. *Pro Cryptography and Cryptanalysis: Creating Advanced Algorithms with C# and. NET*. Apress, 2021.
   3.

Reference Books

5. Gaines, Helen F. *Cryptanalysis: A study of ciphers and their solution*. Courier Corporation, 2014.
6. Wagstaff Jr, Samuel S. *Cryptanalysis of number theoretic ciphers*. Chapman and Hall/CRC, 2019.
7. Derbez, Patrick. Tools and Algorithms for Cryptanalysis. Diss. Université Rennes 1, 2022.

8. **Petrenko, Alexei. Applied Quantum Cryptanalysis. CRC Press, 2023.**

Course Code	Course Name	L – T – P	**Credits**
CE699	**Internet of Things**	3-0-2	**4**

Course Objective:

Prerequisite:

Course Contents

Syllabus Description

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 IoTenablingTechnologies, 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 & Cloudofferings, Software environments, NEO, Security

Course Outcomes

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

CO1: Students are able to understand Basic Principles of Software Engineering and Design

CO2: Students are able to create Use Cases and develop Use Case Models of the Systems.

CO3: Students are able to apply UML design notations to develop the software systems

CO4: Able 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)
3. “Designing the internet of things”, McEwen, Adrian, and Hakim Cassimally. John

Wiley& Sons, 2013. 4. Research Papers discussed in the classroom discussions
Reference Books
1. Jochen Schiller, "Mobile Communication", 2nd Edition, Pearson Education. 2. Yi Bing Lin and ImrichChlamtac, "Wireless and Mobile Networks Architecture", John Wiley & sons, 2001. 3. Ed Burnette, "Hello Android", Pragmatic Bookshelf; Third Edition edition, 2010. 4. Yan Zhang, Jun Zheng, Miao Ma, ―Handbook of Research on Wireless Security‖, Volume 1, Idea Group Inc (IGI), 01-Jan-2008. 5. Raj Kamal, ―Mobile Computing‖, illustrated edition, Oxford University Press, Oxford higher education, 2007.

Course Code	Course Name	L – T – P	**Credits**
CE691	**SECURE WIRELESS SENSOR NETWORKS**	3-0-2	**4**
Course Objective: To meet End-User, Network-Administrator and Network-Designer perspectives **Prerequisite**: Computer Networks Fundamentals, Programming			
Course Contents **Syllabus Description** **Unit I:** Introduction, WSN Resources & constraints, Relevance to IoTs, Relevance to Cyber-Physical Systems, Relevance to Network Centric Operations, Relevance to Data Stream Management Systems, Relevance to the increasing demand of high performance computations, SCADA, battle sensor. **Unit II:** WSN Network Architecture, MAC Layer protocols, Naming and Addressing, Synchronization, Location & positioning, Topology control, Connected Dominating Sets, Routing Protocols, Data-Centric & Content-based networking, Data-Centric querying, WSNs versus IoTs **Unit III:** Vulnerabilities, threats, attacks & safeguards in WSN, key distribution methods & protocols, multi-party computations inclusion, RF-Id communications, open source hardware concept, Security goals for WSNs, Attacks on WSNs: Passive & Active Attacks, Security Mechanisms, Security Models for WSNs, Challenges in WSNs: with respect to wireless medium, resource scarcity, ad-hoc deployments, hostile environments, immense scale, etc. Application oriented: Secure Wireless Networks.			
Text Books			

1. **FUNDAMENTALS OF WIRELESS SENSOR NETWORKS: THEORY AND PRACTICE, Authors: Waltenegus Dargie, Technical University of Dresden, Germany, Christian Poellabauer, University of Notre Dame, USA, Wiley, First Edition, 2010**

Reference Books

1. Ian F. Akykildiz, Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci, ―A Survey on Sensor Networks‖, IEEE Communication Magazine, year 2002.
2. Culler, D. E and Hong, W., ―Wireless Sensor Networks‖, Communication of the ACM, Vol. 47, No. 6, June 2004, pp. 30-33.
3. Adrian Perrig, John Stankovic, David Wagner, ―Security in Wireless Sensor Networks‖ Communications of the ACM, Page53-57, 2004
4. Chris Karlof, David Wagner, ―Secure Routing in Wireless Sensor Networks: Attacks and Countermeasures‖, AdHoc Networks (elsevier), Page: 299-302, year 2003
5. Al-Sakib Khan Pathan, Hyung-Woo Lee, Choong Seon Hong, ―Security in Wireless Sensor Networks: Issues and Challenges‖, International conference on Advanced Computing Technologies, Page1043-1045, year 2006
6. John Paul Walters, Zhengqiang Liang, Weisong Shi, Vipin Chaudhary, ―Wireless Sensor Network Security: A Survey‖, Security in Distributed, Grid and Pervasive Computing Yang Xiao (Eds), Page3-5, 10-15, year 2006
7. Pathan, A.S.K.; Hyung-Woo Lee; Choong Seon Hong, ―Security in wireless sensor networks: issues and challenges‖ Advanced Communication Technology (ICACT), Page(s):6, year 2006
8. Tahir Naeem, Kok-Keong Loo, Common Security Issues and Challenges in Wireless Sensor Networks and IEEE 802.11 Wireless Mesh Networks, International Journal of Digital Content Technology and its Applications, Page 89-90 Volume 3, Number 1, year 2009
9. Undercoffer, J., Avancha, S., Joshi, A. and Pinkston, J. ―Security for sensor networks‖. In Proceedings of the CADIP Research Symposium, University of Maryland, Baltimore County, USA, year 2002 http://www.cs.sfu.ca/~angiez/personal/paper/sensor-ids.pdf
10. Zia, T.; Zomaya, A., ―Security Issues in Wireless Sensor Networks‖, Systems and Networks Communications (ICSNC) Page(s):40 – 40, year 2006
11. Xiangqian Chen, Kia Makki, Kang Yen, and Niki Pissinou, Sensor Network Security: A Survey, IEEE Communications Surveys & Tutorials, vol. 11, no. 2,page(s): 52-62, year 2009
12. D. Djenouri, L. Khelladi, and N. Badache, ―A Survey of Security Issues in Mobile ad hoc and Sensor Networks,‖ IEEE Commun. Surveys Tutorials, vol. 7, pp. 2–28, year 2005.
13. S. Schmidt, H. Krahn, S. Fischer, and D. Watjen, ―A Security Architecture for Mobile Wireless Sensor Networks,‖ in Proc. 1st European Workshop Security Ad-Hoc Sensor Networks (ESAS), 2004.
14. Y. Wang, G. Attebury, and B. Ramamurthy, ―A Survey of Security Issues in Wireless Sensor Networks,‖ IEEE Commun. Surveys Tutorials, vol. 8, pp. 2–23, year 2006.
15. Yun Zhou, Yuguang Fang, Yanchao Zhang, Securing Wireless Sensor Networks: A Survey, IEEE Communications Surveys & Tutorials, year 2008
16. Xiuli Ren, Security Methods for Wireless Sensor Networks, Proceedings of the 2006 IEEE International Conference on Mechatronics and Automation , Page:

1925 ,year 2006

17. R.Roman, J. Zhou, and J. Lopez, ―On the security of wireless sensor networks,‖ in International Conference on Computational Science and Its Applications – ICCSA 2005, May 9-12 2005, vol. 3482 of Lecture Notes in Computer Science, (Singapore), pp. 681– 690, Springer Verlag, Heidelberg, D-69121, Germany, 2005.
18. N. Sastry and D. Wagner, ―Security considerations for ieee 802.15.4 networks,‖ in Proceedings of the 2004 ACM workshop on Wireless security, pp. 32–42, Philadelphia, PA, USA: ACM Press, 2004.
19. WSN Security Models: Refer 4 papers: Paper 1: Wireless sensor network security model using zero knowledge protocol, ICC 2011; Paper 2. An energy efficient link-layer security protocol for wireless sensor networks, EIT 2007; Paper 3. Toward resilient security in wireless sensor networks, MobiHoc 2005; Paper 4. TinySec: a link layer security architecture for wireless sensor networks, SenSys 2004.

Course Code	Course Name	L – T – P	**Credits**
CS-613	**Security Standards & Penetration Testing**	3-0-2	**4**

Course Objective:

This course examines the methods for securing information existing in different forms. This course will provide an introduction to the different technical and administrative aspects of Information Security and Assurance. Also, one cannot protect his information assets if he doesn't know how attackers think and what techniques attackers use to exploit systems. Hence, learning offensive security techniques like Ethical Hacking and penetration testing is becoming a need of future cyber security world. Objectives are: 1. To facilitate individual in gaining knowledge on information security management systems,.2. To facilitate individual in gaining knowledge on security standards like ISO-27001 standards, TCSEC, ITSEC, Secure coding etc. 3. To train individual to become competent information security professional by learning both theoretical as well as practical ethical hacking and penetration testing knowledge base

Prerequisite:

Basic computer networking, operating systems and computer programming knowledge is required.

Course Contents **Unit I**: **(16 Hrs; T1)** Introduction to Information security, Concepts, Threats, Attacks, and Assets, Security Functional Requirements, Countermeasures , Access Control Principles, Access Rights , Discretionary Access Control, Role - Based Access Control, Mandatory Access Control , Trusted Computing and Multilevel Security, 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)	CO1, CO3
Unit II: **(13 Hrs; T2,3)** 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, Penetration Testing Methodologies Security Assessments, Penetration Testing Methodologies, Penetration Testing Steps, Setting up own virtual ethical hacking lab for experimentation, Ethical Hacking and penetration Basics - Hacking terminology & attacks, Ethics, Legality.	
Unit III : (12 Hrs; T2,3,4,5,6) Phases - Reconnaissance, Scanning,Gaining access, Maintaining access, Covering tracks; 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 Scansdetecting OS fingerprinting, banner grabbing, Null Sessions, SNMP/DHCP/DNS enumeration, Proxy Servers, Anonymizers, HTTP Tunneling Techniques, IP Spoofing Techniques; Cryptographic Techniques	CO2,
Unit IV: (10 Hrs; T4,6) Attacking System and Maintaining Access– Password/hashcracking, NetBIOS DoS Attacks, PasswordCracking Countermeasures; escalating privileges - exploiting vulnerabilities, Buffer Overflows,Rootkits, Hiding FilesNTFS Stream Countermeasures, Steganography Technologies, Cover tracks and Erase Evidence, Disabling Auditing, Clearing the event Log, Malware attacks-Trojan, Backdoor, Viruses, Worms, DoS/DDoS; Attacks, Windows Hacking; Linux Hacking; Web and Database Hacking; Google Hacking; Wireless Hacking; Mobile Hacking; Penetration Testing Tools like Kali Linux, Metasploit ,Pen-Test Deliverables	CO2
Lab Assignments 1 Study Windows Essential Tools-Part 1 Unit -1 02hours 2 Study Windows Essential Tools-Part 2 Unit -1 02hours 3 Study Sysinternals utilities to manage, diagnose, troubleshoot, and monitor a Microsoft Windows environment Unit -2 02hours 4 Study passive information gathering tools. Unit -3 02hours 5 Write Security Policy Document Unit -3 04hours 6 Case study: LDRA and Parasoft tools Unit -3 02hours 7 Kali Linux Attacks – Part1 Unit -3 02hours 8 Kali Linux Attacks – Part2 Unit -4 04hours 9 SSPT Practice Test -1QuizUnit -4 04hours 10 Apply data mining tools for cyber security related data analysis Unit 02hours	CO1,2,3,4 CO1,3,4 CO2,3,4 CO1,3,4 CO1,4 CO2,3 CO3,4 CO2,3 CO2,4 CO1,2,3,4
Course Outcomes	

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

CO1: Students will able to identify and apply basic concepts, terminology, theories, models and methods in the field of information security management field. (PO1, PO3, PSO1).

CO2: Student will able to design policies for managing information security effectively adhering to ISO-27001 standards, TCSEC, ITSEC, Secure coding practices etc. (PO1, PO2, PO3, PSO1)

CO3: Student will learn to design, implement, integrate and manage various security countermeasures/tools/mechanisms/best practices and penetration testing through hands-on activities. (PO1, PO3, PSO1) attacks like Network Intrusion, DDOS, Malware attacks are carried out successfully by attackers. (PO1, PO2, PO3, PSO1, PSO2)

CO4: - End semester Exam

Text Books

3. Michael E Whitman, Herbert J Mattord, "Principles of Information Security", Course Technology, 3rd Edition, 2008.
4. William Stallings and Lawrie Brown, "Computer Security: Principles and Practice", 2nd edition, Pearson, 2012.
5. Krutz, R. L. & Vines, R. D., "The CISSP and CAP Prep Guide", Platinum Edition, New York, Wiley Publishing., 2006.
6. Nina Godbole, "Information Systems Security: Security Management, Metrics, Frameworks and Best Practices", Wiley India Pvt Ltd, 2012.
7. Dhavale, S. V. (2019). Constructing an Ethical Hacking Knowledge Base for Threat Awareness and Prevention (pp. 1-305). Hershey, PA: IGI Global.
8. 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 MatiAharoni, "Metasploitpentest guide",No starch Press, san Francisco, 2011
5. Bastian ballman, "Understanding n/w hacks:attack and defense with python", Springer,2012
6. Rich Annings, HimanshuDwivedi, Zane Lackey, "Hacking Exponsed Web 2.0", Tata Mcgraw hill Edition

   Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/IBM/EC-Council sources

Course Code	Course Name	L – T – P	**Credits**
CE694	**Big Data Analysis & Algorithms**	3-0-2	**4**

Course Objective:

1. The use of Big Data is becoming a crucial way for leading companies to
2. outperform their peers. In most industries, established competitors and new entrants alike will leverage data-driven strategies to innovate, compete, and capture value. Early adopters of Big Data are using data from sensors embedded in products from children's toys to industrial goods to determine how these products are actually used in the real

world. Such knowledge then informs the creation of new service offerings and the design of future products. Big Data will help to create new growth opportunities and entirely new categories of companies. With everything going digital, data is pouring in from all kinds of sources imaginable. Organisations are getting inundated with terabytes and petabytes of data in different formats from sources like operational and transactional systems, customer service points, and mobile and web media. The problem of such huge data is storage and with no proper utilisation of the data, collecting and storing is a waste of resource. Earlier it had been difficult to process such data without relevant technology. Big data analytics is becoming an integral part of organisations who want to grow in this age of innovation and is being done by most of the big companies. There is huge scope of big data analytics professionals as this is going to be an essential part of companies in the future. 3. **The Need:** (a) Cyber-Security Perspective: As the complexity of IT networks has grown, the inventiveness and sophistication of cyber security threats and attacks has grown just as quickly. As malware attacks increase in volume and complexity, it's becoming more difficult for traditional analytic tooling and infrastructure to keep up thanks to the Data volume, For example, every day at Sophos Labs, over 300,000 new potentially malicious files that require analysis are reported. Scalability: SQL-based tooling and infrastructure doesn't scale well and is costly to maintain. Big Data Analytics is a Path Forward to Cyber Security. (b) AI / Intelligent Systems Perspective: Centre for Big Data Analytics and Intelligent Systems focuses on the theory development, novel techniques and smart solutions of big data analytics in broad domains, along with theories and techniques of building computer systems, which capture the intelligent behaviours in complex environments. AI dwells on Big Data. (c) Multi-Disciplinary Course useful to any engineering discipline who use a computer. **Prerequisite:** Basic computer networking, operating systems and computer programming knowledge is required.	
Course Contents **Unit I**: **(8 Hrs; T1)** Introduction to big data analysis: Evolution of data, data streams, database models, graph data, normalizations, structured & unstructured data	CO1,2
Unit II: **(4 Hrs; T1)** Architectures, Adoption, Frameworks that enable big data analytics, Multi-Dimensional Data Models, Data cube Computations	CO1
Unit III : (6 Hrs; T1) 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	CO1,2
Unit IV: (6 Hrs; T1) 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	CO3

Processors, Hardware and Cluster Platforms for Big Data Analytics, Big Data Next Challenges – IoT, Cognition, and Beyond **Unit V: (6 Hrs; T1)** Big Data Storage & Processing Concepts Relational database technology, Parallel and Distributed Processing capabilities, Clouds, MapReduce Framework **Unit VI: (6 Hrs; T1)** 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	 CO3 CO4
Lab Assignments	
1 Describe the Use Case*. Model the case study. Abstract. Apply & implement DDL. (Unit-1 02 hours)	CO1
2 Data Manipulation Language (DML) and Data Control Language (DCL) (Unit-2 02 hours)	CO2
3 Apply, analyse and evaluate ACID Properties. High level language extensions with cursors. High level language extension with Triggers. (Unit-3 & 4 02 hours)	C03
4 Implement and apply Multi-dimensional DBs. Implement three basic operations: Perform Diagnostic Analysis (Unit 4 & 5 02 hours)	CO3
5 Implement and apply Multi-dimensional DBs. Implement operations to observe 'what-if' analysis: Perform Predictive Analysis (Unit 4 & 5 02 hours)	CO4
6 Create use case environment, Implement & Perform Data Flow wrt Application/Domain Control(Unit 6 02 hours)	CO4
7 Create use case environment, implement & perform Inter-environment mappings and data pre-processing to apply to AIML model.(Unit 6 02 hours)	CO4

Course Outcomes

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

CO1: Students will able to identify and apply basic concepts, terminology, theories, models and methods in the field of information security management field. (PO1, PO3, PSO1).

CO2: Student will able to design policies for managing information security effectively adhering to ISO-27001 standards, TCSEC, ITSEC, Secure coding practices etc. (PO1, PO2, PO3, PSO1)

CO3: Student will learn to design, implement, integrate and manage various security countermeasures/tools/mechanisms/best practices and penetration testing through hands-on activities. (PO1, PO3, PSO1) attacks like Network Intrusion, DDOS, Malware attacks are carried out successfully by attackers. (PO1, PO2, PO3, PSO1, PSO2)

CO4: - End semester Exam

Text Books

Text Book 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 Text Book-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
Reference Book-1 Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006

Department of Applied Mathematics

Department of Applied Mathematics

Introduction: 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 department is offering two **MTech programmes in Data Science and Modelling & Simulation and one MSc programme in Data Science**.

The faculty of Department of Applied Mathematics has been actively involved in the research in different fields of applied mathematics such as Numerical Solution to PDEs, Optimization, Statistics, Probability, Neural Network, Fuzzy Logic and Genetic Algorithm, Parallel Computing, Cryptography and Machine Learning, Deep Learning, Medical Imaging, Digital Image processing, ballistics, flight dynamics, hydro-dynamics, hydro-ballistics, etc.

The Department of Applied Mathematics has dedicated classrooms for all programmes equipped with state-of-the-art teaching facilities and seating arrangement. All faculty in the department are doctorates from prestigious institutes from India and abroad with expertise in the area of Modelling & Simulation, Computer Vision, Heat and Mass transfer, Fluid Dynamics, Numerical Analysis, Machine Learning, Statistical Analysis, Data Analytics, Deep Learning, Finite Element Methods, Fictious Domain Methods, Domain Decomposition Methods, Finite Difference Methods, Federated Learning, Responsible AI, Continuial Learning, High Performance Computing, Distributed Learning, Digital Image & Signal Processing, Medical Imaging, Computational Instrumentation, Prognostics and Health Management, etc.

The Department has four dedicated labs for computing and research work with high end workstations and equipped with MATLAB, python and R languages for performing alalytics and implementing and training deep learning models. The department of Applied Mathematics has organized conferences in the related areas as well as conduct capsule courses/workshops for students, scholars, tri-services officers, scientists, etc in the area of Mathematical and Data Sciences.

The Modelling & Simulation programme is a flagship course of DIAT which is more than four decades old. The department has a strong alumni group of reserachers, serving scientists, armed forces officers, and academicians who help the board of studies to enrich the curriculum to the industry and defence requirements of the country.

The faculty of Department of Applied Mathematics strives for excellence in contributing to the defence forces by solving problems in mathematical domians by taking up various research projects in the area of numerical analysis, fluid dynamics, machine learning, maritime navigation and mapping, surveillance, heat and mass transfer.

M.Tech. in Data Science

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, 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), 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) Knowledge in computer programming is desirable 3) Valid GATE Score in CSE / IT / ECE / ME / AE / CE / EE / IN / MA / ST

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

Semester I:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T /P	
1.	AM 603	Optimization Techniques	3	1	4
2.	AM 604	Advanced Statistical Techniques	3	1	4
3.	AM 605	Linear Algebra and Applications	3	1	4
4.	AM 608	Data Structures and Algorithms	3	1	4
5.	AM 609	Data Science: Tools and Techniques	3	1	4
6.	AM 610	Data Analysis and Visualization	3	1	4
7.	PGC 601	Research Methodology and IPR	2	0	2
		TOTAL	20	6	26

Semester II:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 623	Machine Learning	3	1	4
2.	AM 624	Big Data Analytics	3	1	4
3.		Elective I (School Elective)	3	1	4
4.		Elective II (School Elective)	3	1	4
5.		Elective III	3	1	4
6.		Elective IV	3	1	4
7.	PGC 602		2	0	2
		TOTAL	20	6	26

Semester III:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 651	M. Tech Dissertation - 1	28**		14
		TOTAL	28		14

Semester IV:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 652	M. Tech Dissertation - 2	28**		14
		TOTAL	28		14

****Contact Hours / week: -**

- ✓ **One credit in Lecture – L (Theory) / Tutorial (T) mean one contact hour and**
- ✓ **One credit in Practical (P) (Lab session) / Thesis mean Two contact hours)**

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 625	Image and Video Analytics
2	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	CE 631	Deep Learning
15	CE 632	Computer Vision
16	CE 691	Secure Wireless Sensor Networks
17	CE 699	Internet of things

Course Code	Course Name	L – T – P	**Credits**
AM 603	**Optimization Techniques**	3-1-0	**4**

Course Objectives:

- Understand the need and origin of the optimization methods.
- Get a broader picture of the various applications of optimization methods used in engineering.
- Define an optimization problem and its various components.
- Formulate optimization problems as mathematical programming problems.
- Classify optimization problems to suitably choose the method needed to solve the particular type of problem.
- Briefly learn about classical and advanced techniques in optimizations.

Course Contents

Unit I

Linear programming: Simplex method, Two-phase method, Big-M method, Duality, Integer linear Programming, Dynamic Programming, Sensitivity analysis.

Unit II

Assignment problem: Hungarian's algorithm, Degeneracy, applications, unbalanced problems, traveling salesman problem.

Unit III

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.

Unit IV

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.

Unit V

CPM/PERT: Simulation of CPM/PERT network, Analysis of an activity network, Simulation of inventory system and manufacturing system.

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.

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, Wieley 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.

Course Code	Course Name	L – T – P	**Credits**
AM 604	**Advanced Statistical Techniques**	3-1-0	**4**

Course Objectives:

- To summarize and present data numerically and visually.
- Knowledge of which statistical methods to use in which situations
- To think critically about data-based claims and quantitative arguments
- To learn new statistical analysis techniques on your own

Course Contents

Unit I

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 II

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.

Unit III
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 IV
Stochastic process: Basic idea of random processes, Stationary, Markov processes, Markov chains and applications, Introduction to ergodicity.

Unit V
Introduction to R- Packages: Scientific Calculator- Inspecting Variables- Vectors Matrices and Arrays-
Lists and Data Frames- Functions- Strings and Factors-Flow Control and Loops- Advanced Looping- Date and Times.

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, Acdemic 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. Speigel, 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.

Course Code	Course Name	L – T – P	**Credits**
AM 605	**Linear Algebra and Applications**	3-1-0	**4**

Course Objectives:

- The concept of vectors, and their linear independence and dependence.
- Rank and nullity of linear transformations through matrices.
- Various applications of vectors in computer graphics and movements in plane.
- To find out how Linear Algebra is ubiquitous in Mathematics and therefore a strong foundation has to be laid in studying the abstract algebraic concepts intertwining geometric ideas.
- The fundamental notions of vector spaces viz linear dependence, basis and dimension and linear transformations on these spaces have to be studied thoroughly

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.

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

Text Books
1. Iterative Methods for Sparse Linear Systems, 2^{nd} Ed., 2003, Y. Saad, SIAM. 2. Introduction to Linear Algebra, 6^{th} Ed., 2023, Gilbert Strang, Wellesley-Cambridge Press.
Reference Books
1. Fundamentals of Matrix Computations, 2^{nd} 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

Course Code	Course Name	L – T – P	**Credits**
AM 608	**Data Structures and Algorithms**	3-0-2	**4**

Course Objectives:

- To provide the knowledge of basic data structures and their implementations.
- To understand importance of data structures in context of writing efficient programs.
- To develop skills to apply appropriate data structures in problem solving.

Course Contents

Unit I

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.

Unit II

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.

Unit III

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.

Unit IV

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.

Course Outcomes

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

CO1 Learn the programming language and get in-depth knowledge of Data structures, and their applications in real world.

CO2 Learn in estimating the complexity of algorithms in terms of space, time and memory.

CO3 Solve problems using sorting, searching, and shortest path finding algorithms and also do the complexity analysis of these algorithms.

CO4 Apply Algorithm for solving problems like sorting, searching, insertion and deletion of data.

Text Books

1. Introduction to Algorithms, 4th Ed., 2022, Thomas H. Cormen, Charles E. Leiserson, The MIT Press.
2. Data Structures and Algorithms in Java, 4th Ed., 2004, M. Goodrich, R. Tamassia, John Wiley and Sons, Inc.

Reference Books

1. An Introduction to Data Structures with Applications, 1986, Jean Paul Tremblay, Paul G. Sorenson, Tata McGraw Hill.
2. Data Structures & Program Design, 1st Ed., 1998, Robert L. Kruse, Pearson.

Course Code	Course Name	L – T – P	**Credits**
AM 609	**Data Science: Tools and Techniques**	3-0-2	**4**

Course Objectives:

- To understand the various concepts in Data Science process.
- To study the applications of Data Science
- To learn to setup data science tools environment and implement in Python
- To learn to write programs in Python for data science
- To know the process of data handling and processing concerning data science.

Course Contents

Unit I

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

Unit II

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

Unit III

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

Unit IV

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.

Unit V

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 Visulization 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

Unit VI

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

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.

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.
2. Expert Python Programming: Best practices for designing, coding, and distributing your Python software Tarek Ziadé, 2008, Packt Publishing.
3. Programming Python, 2010, Mark Lutz, O'Reilly Media.
4. Programming in Python 3: A Complete Introduction to the Python Language, 2010, Mark Summerfield, Addison-Wesley.
5. Practical programming: An introduction to computer science using Python, 2009, Jennifer Campbell, Paul Gries, Jason Montojo, Greg Wilson, Pragmatic Bookshelf.
6. Core Python Programming, 2nd Ed., 2006, Wesley Chun, Prentice Hall.
7. Core Python Applications Programming, 2012, Wesley J Chun, Prentice Hall.
8. Programming Computer Vision with Python: Tools and algorithms for analyzing images, 2012, Jan Erik Solem, O'Reilly Media.

Course Code	Course Name	L – T – P	**Credits**
AM 610	**Data Analysis and Visualization**	3-0-2	**4**

Course Objectives:

- To summarize concepts of data quality. Understand and describe the impact of data on actuarial work and projects.
- To understand the categories of data quality principles. Given a principle of data quality, provide an example that illustrates the principle.
- To understand what is involved in a review of data.
- To understand the broad classifications of data: quantitative vs qualitative; nominal, ordinal, interval continuous;.

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).

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.

Text Books

1. 1.Python for data analysis: Data wrangling with Pandas, NumPy, and IPython, 2012, W. McKinney, O'Reilly Media,

Reference Books

1. Information Visualization: Perception for Design, 2nd Ed., 2004, C. Ware, Morgan Kaufmann.
2. A Byte of Python: Python Tutorial, 2003, C. H. Swaroop.
3. Business Statistics for Contemporary Decision Making, 4th Ed., 2003, Ken Black, John Wiley & Sons, Inc.
4. Statistics for Business and Economics : Cengage Learning, 13th 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, 3rd 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.Visualization Handbook, 2004, C .D. Hansen, C. R. Johnson, Academic Press, 2004.

Course Code	Course Name	L – T – P	**Credits**
AM 623	**Machine Learning**	3-0-2	**4**

Course Objectives:

- To understand the basic theory underlying machine learning.
- To be able to formulate machine learning problems corresponding to different applications.
- To understand a range of machine learning algorithms along with their strengths and weaknesses.
- To be able to apply machine learning algorithms to solve problems of moderate complexity.
- To apply the algorithms to a real-world problem, optimize the models learned and report on the expected accuracy that can be achieved by applying the models.

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

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

CO1 Understand the scenarios where machine learning algorithms can and cannot be used. Understand different types of machine learning algorithms namely unsupervised, supervised, and reinforcement learning algorithms, and get exposure to scenarios/applications where these algorithms can be applied.

CO2 learn the concepts of Regression, Classification and Clustering algorithms, and how to choose metrics to evaluate the performance of various machine learning models.

CO3 understand the concepts of overfitting, underfitting, right fit while learning a machine learning model, and learns the different techniques to address overfitting, underfitting problems to obtain the right fit. Students also learns how to setup a machine learning experiment, and how to report the performance of the model. **CO4** acquire knowledge on programming languages such as Python, Matlab, R, and also on libraries like NumPy, Pandas, Matplotlib, Scikit learn, etc. which helps them to apply machine learning models on any data sets.
Text Books
2. Machine Learning, Indian Ed., 2017, Tom M. Mitchell, Tata McGraw Hill Education. 3. Machine Learning: An Algorithmic Perspective, 2nd Ed., 2014, Stephen Marsland, Taylor & Francis (CRC). 4. Machine Learning, A probabilistic perspective, 2012, Kevin Murphy, MIT Press. 5. 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.

Course Code	Course Name	L – T – P	**Credits**
AM 624	**Big Data Analytics**	3-0-2	**4**

Course Objectives:

- To understand the Big Data Platform and its Use cases
- To understand the overview of Apache Hadoop
- To learn HDFS Concepts and Interfacing with HDFS
- To understand Map Reduce Jobs
- To provide hands-on Hadoop Eco System

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.

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

Text Books

1. Big Data Fundamentals: Concepts, Drivers & Techniques 2016 by Thomas Erl, Wajid Khattak, Paul Buhler, Publisher: Prentice Hall, 2016), Service Tech Press
2. Seema Acharya, Subhashini Chellappan, "Big Data and Analytics", Wiley Publication, 2015.

Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006

Reference Books

1. Introduction To Algorithms, 3rd Ed., 2009, Thomas H. Cormen, Charles E. Leiserson, Ronaldo L. Rivest, Clifford Stien, The MIT Press.

2. Big Data for Dummies, 2013, Judith Hurwitz, Alan Nugent, Dr. Fern Halper, Marcia Kaufman, John Wiley & Sons, Inc.
3. Hadoop: The Definitive Guide, 2012, 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 and Jeffrey David Ulman, Cambridge University Press.
6. Big Data Analytics, 2015, Seema Acharya, Subhasini Chellappan, Wiley.
7. Big Data Fundamentals: Conpts, Drivers & Techniques, 2016, Thomas Erl, Wajid Khattak, Paul Buhler, Prentice Hall, Service Tech Press.

Data Mining, 2nd Ed., 2006, Jiawei Han & Micheline Kamber, Elsevier.

Course Code	Course Name	L – T – P	**Credits**
AM 625	**Image and Video Analytics**	3-0-2	**4**

Course Objectives:

- To understand the basics of image processing techniques for computer vision.
- To learn the techniques used for image pre-processing.
- To discuss the various image segmentation techniques.
- To elaborate on the video analytics techniques

Course Contents

Unit I

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.

Unit II

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.

Unit III

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.

Unit IV

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.

Unit V

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

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

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.

Course Code	Course Name	L – T – P	**Credits**
AM 627	**Information Theory and Coding**	3-1-0	**4**

Course Objectives:

- To understand the information theoretic behavior of a communication system.
- To understand various source coding techniques for data compression
- To understand various channel coding techniques and their capability.
- To Build an understanding of fundamental concepts of data communication and networking.

Course Contents

Unit I

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

Unit II

Cyclic Codes: Polynomial Representation of Code words, Generator Polynomial, Systematic Codes, Generator Matrix, Syndrome Calculation and Error Detection, Decoding of Cyclic Codes

Unit III

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

Unit IV

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

Unit V

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

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.
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. 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, 2^{nd} Ed., 2006, T. M. Cover, J. A. Thomas, WielyInterscience. 6. Coding and information theory, 1980, R. W. Hamming, Prentice Hall Inc. Entropy and Information Theory, 2^{nd} Ed., 2011, Robert M. Gray, Springer, 2011.

Course Code	Course Name	L – T – P	**Credits**
AM 628	**Computational Number Theory and Cryptography**	3-1-0	**4**

Course Objectives:

- The course aims to give elementary ideas from number theory which will have applications in cryptology.
- Identify and apply various properties of and relating to the integers including the Well-Ordering Principle, primes, unique factorization, the division algorithm, understand the concept of a congruence,
- To impart the knowledge of encryption and decryption techniques and their applications in managing the security of data.

Course Contents

Unit I

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

Unit II

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,

Unit III

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.

Unit IV

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.

Unit V

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.

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.
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. An Introduction to theory of numbers, 2006, I. Niven, H.S. Zuckerman, H.L. Montgomery, John Wiley & Sons, Inc.
Reference 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, 2nd 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, 5th Ed., 2004, K. Rosen, Addison Wesley. 10. Factorization and Primality Testing, 1989, D. M. Bressoud, Springer-Verlag. 11. A computational introduction to number theory and algebra, 2009, V. Shoup, Cambridge University Press. 12. Mathematics for computer algebra, 1992, M. Mignotte, Springer-Verlag. 13. An introduction to the theory of numbers, 2011, I. Niven, H. S. Zuckerman, H. L. Montgomery, John Wiley. 14. Modern computer algebra, 3rd Ed., 2013, J. Von zur Gathen, J. Gerhard, Cambridge University Press. 15. Introduction to finite fields and their applications, 2012, R. Lidl, H. Niederreiter, Cambridge University Press. 16. Applications of finite fields, 1993, A. J. Menezes, Kluwer Academic Publishers. 17. Rational points on elliptic curves, 2015, J. H. Silverman, J. Tate, Springer International Edition. 18. Guide to elliptic curve cryptography, 2004, D. R. Hankerson, A. J. Menezes, S. A. Vanstone, Springer-Verlag. 19. Public-key cryptography: Theory and practice, 2009, A. Das, C. E. Veni Madhavan, Pearson Education Asia. 20. A course in computational algebraic number theory, 1993, H. Cohen, Springer-Verlag.

Course Code	Course Name	L – T – P	**Credits**
AM 635	**Finite Elements: Theory and Algorithms**	3-1-0	**4**

Course Objectives:

- To learn basic principles of finite element analysis procedure.
- To learn the theory and characteristics of finite elements that represent engineering structures.
- To learn and apply finite element solutions to structural, thermal, and dynamic problems to develop the knowledge and skills needed to effectively evaluate finite element analyses.

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.

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.

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.

Course Code	Course Name	L – T – P	**Credits**
AM 635	**Cloud Computing**	3-1-0	**4**

Course Objectives:

- To provide students with the fundamentals and essentials of Cloud Computing.
- To provide students with a sound foundation of Cloud Computing so that they can start using and adopting Cloud Computing services and tools in their real-life scenarios.
- To enable students to explore some important cloud computing-driven commercial systems and applications.
- To expose the students to frontier areas of Cloud Computing and information systems, while providing sufficient foundations to enable further study and research.

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

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.

Text Books
1. Distributed and Cloud Computing: From Parallel Processing to the Internet of Things, 2011, Kai Hwang, Jack Dongarra and Geoffrey Fox, Morgan Kaufmann. 2. Cloud computing a practical approach, 2010, Anthony T.Velte , 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, Rajkumar Buyya, James Broberg, Andrzej Goscinski, John Wiley & Sons, Inc.

Course Code	Course Name	L – T – P	**Credits**
AM 637	**Generative AI**	3-0-2	**4**

Course Objectives:

- To understand the fundamental concepts and techniques of generative AI.
- To Apply generative models to generate new content and enhance existing data.
- To Utilize generative AI techniques to solve complex problems in different domains.

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), DeepBelief 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

Course Outcomes
After completing this course, the students will be able to: CO1: Understand the concepts and needs of Generative modelling CO2: Learn the concepts of probability and modelling CO3: Learn the recent advancements in the area of deep learning in Generative AI CO4: Handle the different varieties of data-like text, audio and images CO5: Apply the learned concepts to generate the data related to specific applications of text, audio, images.
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.

Course Code	Course Name	L – T – P	**Credits**
AM 638	**Reinforcement Learning**	3-1-0	**4**

Course Objectives:

- To explore a computational approach to learn from the environment.
- To Introduce key concepts and application of Reinforcement learning keeping in my both theoretical background and practical applications.
- To provide a bottom up approach: starting from foundation in Markov decision processes (MDP) to the state-of-the-art RL algorithms

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

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

Text Books

1. Reinforcement Learning, 2nd 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.

Course Code	Course Name	L – T – P	**Credits**
AM 639	**Deep Learning for Computer Vision**	3-0-2	**4**

Course Objectives:

- To introduce the idea of artificial neural networks and their architecture.
- To introduce techniques used for training artificial neural networks.
- To enable design of an artificial neural network for classification.
- To enable design and deployment of deep learning models for machine learning 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, 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.

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.

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.

Course Code	Course Name	L – T – P	**Credits**
AM 640	**AI for Medical Image Analysis**	3-0-2	**4**

Course Objectives:

- To solve problems at the interface of computer science, imaging and medicine.
- To explain how digital images are represented, manipulated and processed.
- To apply advanced image processing algorithms to medical images to derive meaningful information.
- To apply supervised and unsupervised machine learning techniques to segment and classify medical images.
- To develop, validate and interpret AI models to gain insight into disease as diagnosed by medical imaging.

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.

Course Outcomes

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

CO1: Understand medical different medical imaging modalities

CO2: Learn the feature extraction schemes specific to imaging modalities

CO3: Design the applications in line with the requirement of medical imaging

CO4: Handling the intricacies of medical data and how to address the,

CO5: Propose and develop a AI solution in Medical Imaging using Open source datasets and custom datasets

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.

Course Code	Course Name	L – T – P	**Credits**
AM 641	**Accelerated Computing**	3-0-2	**4**

Course Objectives:

- **To understand the hardware architechture of CPU GPU configuration**
- **To understand the HPC implementation**
- **To understand the application of algorithms in accelerated environment**

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
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.
Text Books
1. Accelerating AI with Synthetic Data, 2020, Khaled El Emam, O'Reilly Media, Inc.
Reference Books
1. Accelerated Optimization for Machine Learning, 1st Ed., 2020 , Zhouchen Lin Huan Li, Springer.

Course Code	Course Name	L – T – P	**Credits**
AM 642	**Computer Vision with Pattern Recognition**	3-0-2	**4**

Course Objectives:

- To introducestudents 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 andobject recognition systems;
- To provide the student with programming experience from implementing computer vision andobject recognition 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

Course Outcomes

After completing this course, the students will be able to:
CO1: Understand the concepts of computer vision with conventional feature engineering
CO2: Learn the different standard architectures of object detection and classification
CO3 : Perform segmentation algorithms in different domains
CO4: Create the datasetss and gets an overview of annotation
CO5: Apply the learned concepts to real world problems in the area of medical imaging, automation, self-driving cars, etc.

Text Books

1. Computer Vision: Algorithms and Applications, 2nd Ed., 2022, Richard Szeliski, Springer.
2. Digital Image Processing, 4th Ed., 2017, Rafael C Gonzalez and Richard E Woods, Pearson.

Reference Books

1. Computer Vision: Models, Learning, and Inferences, 1st Ed., 2012, Simon J D Prince, Cambridge University.
2. M. Pattern Recognition and Machine Learning, 2006, Christopher Bishop, Springer.
3. Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press.

Course Code	Course Name	L – T – P	**Credits**
AM 643	**Database Systems**	3-0-2	**4**

Course Objectives:

- Discuss Database management systems, databases and its applications
- Familiarize the students with a good formal foundation on the relational model.
- Outline the various systematic database design approaches
- Describe the concepts of transactions and transaction processing and the issues, techniques related to concurrency and recovery manager.
- Explore the File organizations, indexing and hashing mechanisms.

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
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
Text Books
1. Data base System Concepts, 7th Ed., 2019, A. Silberschatz, H. F. Korth, S. Sudarshan, McGraw hill. 2. Data base Management Systems, 3rd Ed., 2002, Raghurama Krishnan, Johannes Gehrke, TATA McGrawHill.
Reference Books
1. Fundamentals of Database Systems, 7th Ed., 2017, Elmasri Navathe, Pearson Education. 2. An Introduction to Database systems, 8th Ed., 2003, C. J. Date, A. Kannan, S. Swami Nadhan, Pearson.

M. Tech in Modelling and Simulation

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 practicals. 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
- Computer Vision
- Machine Learning
- Deep Learning

Programme Outcomes (POs)

PO1	The programme 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) Knowledge in computer programming is desirable 3) Valid GATE Score in CSE / IT / ECE / ME / AE / CE / EE / IN / MA / ST

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

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	1	4
2.	AM 602	Mathematical Modelling & System Analysis	3	1	4
3.	AM 603	Optimization Techniques	3	1	4
4.	AM 604	Advanced Statistical Techniques	3	1	4
5.	AM 605	Linear Algebra and Applications	3	1	4
6.	AM 609	Data Science: Tools & Techniques	3	1	4
7.	PGC 601	Research Methodology and IPR	2	0	2
		Total	**20**	**6**	**26**

Semester II:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AM 621	Advanced Modelling Techniques	3	1	4
2.	AM 622	Simulation of Linear and Nonlinear Systems	3	1	4
3.		Elective I [From School]	3	1	4
4.		Elective II [From School]	3	1	4
5.		Elective III	3	1	4
6.		Elective IV	3	1	4
7.	PG -602	Communication Skills & Personality Development	2	0	2
		Total	**20**	**6**	**26**

Semester III:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AM 651	M.Tech Dissertation Phase – I	28**		14
		Total	**28**		**14**

Semester IV:

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1.	AM 652	M.Tech Dissertation Phase - II	28**		14
		Total	**28**		**14**

***** 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/ weekNote: During summer vacation (4 Weeks), Summer 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 623	Machine Learning
2	AM 624	Big Data Analytics
3	AM 625	Image and Video Analytics
4	AM 626	Computational Heat and Mass Transfer
5	AM 627	Ballistics
6	AM 628	Computational Number Theory and Cryptography
7	AM 629	Calculus of Variations and Integral Equations
8	AM 630	Domain Decomposition Methods for Partial Differential Equations
9	AM 631	Multigrid Methods
10	AM 632	Introduction to Non-Newtonian Fluids
11	AM 633	Bio-Mechanics
12	AM 635	Finite Elements: Theory and Algorithms
13	AM 636	Cloud Computing
14	AM 640	AI for Medical Image Analysis
15	AM 642	Computer Vision with Pattern Recognition
16	CE 631	Deep Learning
17	CE 632	Computer Vision

Course Code	Course Name	L – T – P	**Credits**
AM 601	**Numerical Methods for Differential Equations**	3-0-2	**4**

Course Objectives:

- Provide students with a thorough understanding of numerical methods for solving differential equations.
- Instruct students on applying numerical methods to real-world engineering and technology challenges.
- Empower students to create and implement efficient numerical solutions.
- Improve students' skills in developing mathematical models and choosing suitable numerical techniques.
- Equip students with the expertise needed to engage in research and devise innovative solutions using numerical methods.

Course Contents

Unit I

Solution of Ordinary Differential Equations: Taylor Series method – Euler and Modified Euler methods – Runge Kutta methods – Multistep methods – Milne's method – Adams Moulton method.

Unit II

Boundary Value Problems and Characteristic Value Problems: The Shooting method – solution through a set of equations – Derivative boundary conditions – Characteristic value problems – Eigenvalues of a matrix by Iteration – The power method.

Unit III

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's problem, and Mixed boundary value problem. Higher order compact (HOC) scheme.

Unit IV

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. Advantages and disadvantages of the FDM.

Course Outcomes

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

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 problems that can be solved by an appropriate Numerical method.

CO2: Students can understand the importance of the 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 can analyze and appreciate the variety of numerical methods such as FDM and FVM that can be applied to solve a specific model.

CO4: Students can implement, develop, and promote research interest in applying numerical methods in problems of Engineering and Technology.

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.

Course Code	Course Name	L – T – P	**Credits**
AM 602	**Mathematical Modelling and System Analysis**	3-0-2	**4**

Course Objectives:

- Equip students with advanced knowledge of mathematical modelling and simulation techniques.
- Enable students to analyze and develop continuous and discrete models for real-world applications using dimensional analysis and system dynamics.
- Teach students to model and approximate complex systems, including time-invariant and nonlinear systems.
- Introduce students to the principles and applications of simulator technology, preparing them for innovative research and development, particularly in advanced technological fields.

Course Contents

Unit I

Mathematical Modelling: Introduction to modelling and simulation, Classification of systems into continuous and discrete, Structural characterization of mathematical model and validation techniques.

Unit II

Modelling Techniques: Dimensional analysis: Concept behind the dimensional approach, Buckingham Pi theorem, Models using the dimensional approach.

Unit III

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.

Unit IV:

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 a system, Block diagram representation, Signal flow graph, and Mason's rule. A generalized modelling approach. Principles of conservation and continuity and Applications. Basics of simulator technology.

Course Outcomes

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

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.

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
1. Introduction to System Dynamics, 1967, J.L. Shearer, A.T. Murphy, H.H. Richardson, Addison& Wesley. 2. Introduction to System Analysis, 1985, T.H. Glisson, McGraw Hill.

Course Code	Course Name	L – T – P	**Credits**
AM 603	**Optimization Techniques**	3-1-0	**4**

Course Objectives:

- Understand the need and origin of the optimization methods.
- Get a broader picture of the various applications of optimization methods used in engineering.
- Define an optimization problem and its various components.
- Formulate optimization problems as mathematical programming problems.
- Classify optimization problems to suitably choose the method needed to solve the particular type of problem.
- Briefly learn about classical and advanced techniques in optimizations.

Course Contents

Unit I

Linear programming: Simplex method, Two-phase method, Big-M method, Duality, Integer linear Programming, Dynamic Programming, Sensitivity analysis.

Unit II

Assignment problem: Hungarian's algorithm, Degeneracy, applications, unbalanced problems, traveling salesman problem.

Unit III

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.

Unit IV

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.

Unit V

CPM/PERT: Simulation of CPM/PERT network, Analysis of an activity network, Simulation of inventory system and manufacturing system.

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.

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, Wieley 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.

Course Code	Course Name	L – T – P	**Credits**
AM 604	**Advanced Statistical Techniques**	3-1-0	**4**

Course Objectives:

- To summarize and present data numerically and visually.
- Knowledge of which statistical methods to use in which situations
- To think critically about data-based claims and quantitative arguments
- To learn new statistical analysis techniques on your own

Course Contents

Unit I

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 II

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 III

Regression modeling for Normal response and quantitative explanatory: Introduction to Statistical Modeling, Variables, Simple and Multiple regressions, Model building, and validation, Comparison of regressions.

Unit IV

Stochastic process: Basic idea of random processes, Stationary, Markov processes, Markov chains and applications, Introduction to ergodicity

Unit V

Introduction to R- Packages: Scientific Calculator - Inspecting Variables - Vectors Matrices and Arrays - Lists and Data Frames – Functions - Strings and Factors - Flow Control and Loops - Advanced Looping - Date and Times.

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
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. Speigel, 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.

Course Code	Course Name	L – T – P	**Credits**
AM 605	**Linear Algebra and Applications**	3-1-0	**4**

Course Objectives:

- The concept of vectors, and their linear independence and dependence.
- Rank and nullity of linear transformations through matrices.
- Various applications of vectors in computer graphics and movements in planes.
- To find out how Linear Algebra is ubiquitous in Mathematics and therefore a strong foundation has to be laid in studying the abstract algebraic concepts intertwining geometric ideas.
- The fundamental notions of vector spaces viz linear dependence, basis and dimension, and linear transformations on these spaces have to be studied thoroughly.

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 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.

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

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

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

Course Code	Course Name	L – T – P	**Credits**
AM 607	**Mathematics for Engineers**	3-1-0	**4**

Course Objectives:

- To provide the students with sufficient knowledge in calculus and matrix algebra, which can be used in their respective fields.
- To develop mathematical skills so that students are able to apply mathematical methods & principles in solving problems from Engineering fields.
- To make aware students of the importance and symbiosis between Mathematics and Engineering.

Course Contents

Unit I

Elements of Probability and Statistics: Basic concepts of Probability, Discrete Probability Distributions (Binomial, Poisson etc.), Continuous Probability Distributions (Normal, Exponential, etc.,).

Unit II

Components of Operations Research:

Introduction to Operations Research, Linear programming (Simplex Method, Revised Simplex Method, Dual simplex, Duality theory), Transportation Models.

Unit III

Linear Algebra:

General (real) vector spaces, Subspaces, Linear Independence of Vectors, Basis and Dimension, Linear Transformations, Span, Norms, Orthogonal basis and Gram-Schmidt Orthogonalization**.**

Unit IV

Ordinary Differential Equations :

Review of solution methods for first order as well as second order equations, Power Series methods. Higher Order Linear Equations, Boundary Value Problems for Second Order Equations.

Unit V

Transform Techniques :

Overview of Laplace transforms, Fourier Transforms, Z transform.

Unit VI

Numerical Methods for ODE and P.D.E.:

Taylor series method – Euler and Modified Euler methods – Runge-Kutta method.
Parabolic, Hyperbolic and Elliptic Equations using finite difference method

Course Outcomes

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

CO1: Students will the needful and essential concepts of mathematics

CO2 Students will understand various numerical techniques which will help in solving complex engineering problems

CO3: Students will learn mathematics for modelling the phal situations and engineering problems

CO4: Students will also learn mathematics for the advanced compute-related problems

Text Books

1. Advanced Engineering Mathematics, 11th Ed, 2010, Erwin Kreyszig, Wiley Eastern.
2. Linear Algebra and its Applications, 4th Ed., 2008, Gilbert Strang, Academic Press.
3. Numerical Methods for Scientists and Engineers, Joe D. Hoffman, Marcel Dekker Inc.
4. Numerical Methods for Engineers, Sixth Edition, Steven Chapra and Raymond Canale, McGraw-Hill Education
5. Elements of Numerical Analysis, 2nd Edition, Radhey S. Gupta, Cambridge University Press
6. Numerical Solutions of Partial Differential Equations: An Introduction, 2nd Ed., 2005, K. W. Morton, D. F. Mayers, Cambridge University Press.

Reference Books

1. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
2. Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.
3. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
4. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
5. Differential Equations and Dynamical Systems, Texts in Applied Mathematics, L. Perko, 3rd Ed., Vol. 7, 2006, Springer Verlag, New York.
6. S. Gupta.. Calculus of Variation, Prentice Hall of India Pvt. Ltd.

Course Code	Course Name	L – T – P	**Credits**
AM 609	**Data Science: Tools and Techniques**	3-0-2	**4**

Course Objectives:

- To understand the various concepts in the Data Science process.
- To study the applications of Data Science
- To learn to set data science tools environment and implement them in Python
- To learn to write programs in Python for data science
- To know the process of data handling and processing concerning data science.

Course Contents

Unit I

Programming Language: Introduction to Python, Programming Interfaces, Spyder, Python script file, Print Message to Standard Output, variables, and data types, Reading Input from the 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 a List, Accessing elements from a 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

Unit II

Python Data Structures: Python Set, Creating Set, Adding/Removing elements to/from 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

Unit III

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

Unit IV

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.

Unit V

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 Visulization 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

Unit VI

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

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.

Text Books

5. Mastering Python for Data Science, 2015, Samir Madhavan, Packt Publishing.
6. Python Machine Learning, 2015, Sebastian Raschka Packt Publishing.
7. Python Basics: A Self-Teaching Introduction, 2018, H. Bhasin, Mercury Learning and Information.
8. 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.
2. Expert Python Programming: Best practices for designing, coding, and distributing your Python software Tarek Ziadé, 2008, Packt Publishing.

3. Programming Python, 2010, Mark Lutz, O'Reilly Media.
4. Programming in Python 3: A Complete Introduction to the Python Language, 2010, Mark Summerfield, Addison-Wesley.
5. Practical programming: An introduction to computer science using Python, 2009, Jennifer Campbell, Paul Gries, Jason Montojo, Greg Wilson, Pragmatic Bookshelf.
6. Core Python Programming, 2nd Ed., 2006, Wesley Chun, Prentice Hall.
7. Core Python Applications Programming, 2012, Wesley J Chun, Prentice Hall.
8. Programming Computer Vision with Python: Tools and algorithms for analyzing images, 2012, Jan Erik Solem, O'Reilly Media.

Course Code	Course Name	L – T – P	**Credits**
AM621	**Advanced Modelling Techniques**	3-1-0	**4**

Course Objectives:

- Students are able to understand advanced modelling techniques such as fuzzy logic, neural networks, chaos theory, and fractals.
- Improve analytical skills in the mathematical foundations and applications of advanced modeling methods.
- Prepare students to innovate and make informed decisions in addressing complex industrial and research challenges.

Course Contents

Unit I:

Fuzzy logic: Basic concepts of fuzzy set, Operation on fuzzy sets, Fuzzy numbers Fuzzy relation, Fuzzification, Fuzzy logic as a generalization of two-valued logic, Fuzzy system, fuzzy control, and fuzzy clustering.

Unit II:

Artificial Neural Networks: Introduction, Neural network representation, Appropriate problems for neural network learning, Perceptions, Multilayer networks, and the backpropagation algorithm, Remarks on the backpropagation algorithm, An illustrative example face recognition Advanced topics in artificial neural networks

Unit III:

Dynamics of Chaos: Introduction to chaos, Lorenz system, Lorenz attractor, Dimension of chaotic attractor, applications in communications.

Unit IV:

Fractals: Introduction to fractals, Types of fractal dimensions, Generation of fractals by mathematical approach, Julia and Mandelbrot sets.

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 in 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.

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.

Reference 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.

Course Code	Course Name	L – T – P	**Credits**
AM622	**Simulation of Linear and Nonlinear Systems**	3-1-0	**4**

Course Objectives:

- Provide students with a fundamental understanding of real systems, mathematical models, types of models, simulation techniques, and their practical applications.
- Familiarize students with the generation of random and pseudo-random numbers, and the generation of random variates using discrete and continuous probability distributions (e.g., uniform, triangular).
- Enhance students' ability to analyze the properties of randomness and independence through hypothesis testing, Chi-square tests, and autocorrelation tests.
- Enable students to comprehend simulation theory as it applies to Queuing, Inventory, and CPM/PERT models, and to implement solutions for industrial and real-world problems.

Course Contents

Unit I:
Simulation of single server and multiple server queuing system. Design (component & organization) 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.

Unit II:
Generation of random numbers, Pseudo-random numbers, Test for random number simulation of probability distribution.

Unit III:
Discrete event simulation: simulation of single server and multiple server queuing system.

Unit IV:
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

Course Outcomes

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

CO1: Students can understand the basic concepts of real systems, mathematical models, types of models, simulation, and their applications.

CO2: Students are be able to understand the importance of the Generation of random numbers, Pseudo-random numbers, and generation of random variates using discrete and continuous probability distributions such as uniform, and 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.

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.

Course Code	Course Name	L – T – P	**Credits**
AM 623	**Machine Learning**	3-0-2	**4**

Course Objectives:

- To understand the basic theory underlying machine learning.
- To be able to formulate machine learning problems corresponding to different applications.
- To understand a range of machine learning algorithms along with their strengths and weaknesses.
- To be able to apply machine learning algorithms to solve problems of moderate complexity.

- To apply the algorithms to a real-world problem, optimize the models learned and report on the expected accuracy that can be achieved by applying the models.

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

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

CO1 Understand the scenarios where machine learning algorithms can and cannot be used. Understand different types of machine learning algorithms namely unsupervised, supervised, and reinforcement learning algorithms, and get exposure to scenarios/applications where these algorithms can be applied.

CO2 learn the concepts of Regression, Classification and Clustering algorithms, and how to choose metrics to evaluate the performance of various machine learning models.

CO3 understand the concepts of overfitting, underfitting, right fit while learning a machine learning model, and learns the different techniques to address overfitting, underfitting problems to obtain the right fit. Students also learns how to setup a machine learning experiment, and how to report the performance of the model.

CO4 acquire knowledge on programming languages such as Python, Matlab, R, and also on libraries like NumPy, Pandas, Matplotlib, Scikit learn, etc. which helps them to apply machine learning models on any data sets.

Text Books

6. Machine Learning, Indian Ed., 2017, Tom M. Mitchell, Tata McGraw Hill Education.
7. Machine Learning: An Algorithmic Perspective, 2nd Ed., 2014, Stephen Marsland, Taylor & Francis (CRC).
8. Machine Learning, A probabilistic perspective, 2012, Kevin Murphy, MIT Press.
9. 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.

Course Code	Course Name	L – T – P	**Credits**
AM 624	**Big Data Analytics**	3-0-2	**4**

Course Objectives:

- To understand the Big Data Platform and its Use cases
- To understand the overview of Apache Hadoop
- To learn HDFS Concepts and Interfacing with HDFS
- To understand Map Reduce Jobs
- To provide hands-on Hadoop Eco System

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 Ecosystems.

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 Ecosystems: 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.

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.

Text Books

1. Big Data Fundamentals: Concepts, Drivers & Techniques 2016 by Thomas Erl, Wajid Khattak, Paul Buhler, Publisher: Prentice Hall, 2016), Service Tech Press
2. Seema Acharya, Subhashini Chellappan, “Big Data and Analytics”, Wiley Publication, 2015.
3. Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006

Reference Books

8. Introduction To Algorithms, 3^{rd} Ed., 2009, Thomas H. Cormen, Charles E. Leiserson, Ronaldo L. Rivest, Clifford Stien, The MIT Press.
9. Big Data for Dummies, 2013, Judith Hurwitz, Alan Nugent, Dr. Fern Halper, Marcia Kaufman, John Wiley & Sons, Inc.
10. Hadoop: The Definitive Guide, 2012, Tom White, O’Reilly Publications.
11. Mongo DB in Action, 2012, Kyle Banker, Manning Publications Company.
12. Mining of Massive Datasets, 2012, Jure Leskovec, Anand Rajaraman and Jeffrey David Ulman, Cambridge University Press.
13. Big Data Analytics, 2015, Seema Acharya, Subhasini Chellappan, Wiley.
14. Big Data Fundamentals: Conpts, Drivers & Techniques, 2016, Thomas Erl, Wajid Khattak, Paul Buhler, Prentice Hall, Service Tech Press.
15. Data Mining, 2^{nd} Ed., 2006, Jiawei Han & Micheline Kamber, Elsevier.

Course Code	Course Name	L – T – P	**Credits**
AM 625	**Image and Video Analytics**	3-0-2	**4**

Course Objectives:

- To understand the basics of image processing techniques for computer vision.
- To learn the techniques used for image pre-processing.
- To discuss the various image segmentation techniques.
- To elaborate on the video analytics techniques

Course Contents

Unit I

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.

Unit II

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.

Unit III

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.

Unit IV

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.

Unit V

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

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

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.

Course Code	Course Name	L – T – P	**Credits**
AM 626	**Computational Heat and Mass Transfer**	3-1-0	**4**

Course Objectives:

- Introduce students to the principles and methodologies of computational heat and mass transfer, emphasizing their practical applications in various industrial contexts.
- Provide students with a comprehensive understanding of convective heat transfer phenomena, including both laminar and turbulent flows, and their analytical solutions.
- Familiarize students with the fundamentals of convective mass transfer, including diffusion processes, species conservation equations, and correlations for mass transfer coefficients.
- Equip students with the skills to apply finite element method techniques to solve one-dimensional and two-dimensional heat and mass transfer problems, including conduction, convection, and mixed convection scenarios.

Course Contents

Unit I

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.

Unit II:

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.

Unit III:

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

Unit IV:

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.

Unit V:

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 nodded 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.

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.

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.

Course Code	Course Name	L – T – P	**Credits**
AM 627	**Ballistics**	3-1-0	**4**

Course Objectives:

- Provide students with a comprehensive understanding of explosives, including their classification and measurement of explosive parameters.
- Educate students on internal ballistics, covering propellants, heat conduction in gun barrels, pressure prediction, and muzzle velocity determination.
- Familiarize students with external ballistics principles, focusing on projectile aerodynamics, stability, drag laws, and projectile motion under various conditions.
- Introduce students to projectile transitional motion, including trajectory modeling, correction factors, and the effects of wind.
- Explore terminal ballistics, emphasizing kinetic energy projectiles, penetration mechanics, and the evaluation of ballistic injuries.
- Enable students to understand the design and defeat of armor, including mechanical properties of armor materials, stress-strain relationships, and ballistic failure modes.
- Educate students on wound ballistics, covering wound characteristics, ballistic injuries assessment, and forensic implications.

Course Contents
Unit I: Explosives: Explosive compounds and explosive mixtures-classification of explosives: Measurement of various explosive parameters **Unit II: 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. **Unit III: 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. **Unit IV: Projectile Transitional Motion:** Motion in vacuum-Motion of point mass-Trajectory modeling-constant corrections to the plane-particle trajectory, biases-variable corrections to the plane-particle trajectory, dispersion-the effect of wind. **Unit V: Terminal Ballistics:** Kinetic Energy projectiles: Penetration into resisting medium-Empirical formulae for the prediction of penetration-Analytical models of failure modes-Numerical methods charges. **Unit VI: Design and Defeat of Armour:** Introduction –Mechanical property requirements-Armour material Characteristics –Armour structure-stress-strain relationship-Waves in rods-Defeat of armour-Failure **Unit VII: Wound Ballistics:** Threshold velocity for penetration of skin, flesh, bones- Nature of wounds on entry, exit-Explosive wounds- Evaluation of injuries caused due to shotgun, rifle, handguns, and country-made firearms- Method of measurement of wound ballistic parameters-post mortem and antemortem firearm injuries
Course Outcomes
After completing this course, the students will be able to: **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.
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.

Course Code	Course Name	L – T – P	**Credits**
AM 628	**Computational Number Theory and Cryptography**	3-1-0	**4**

Course Objectives:

- The course aims to give elementary ideas from number theory which will have applications in cryptology.
- Identify and apply various properties of and relating to the integers including the Well-Ordering Principle, primes, unique factorization, the division algorithm, understand the concept of a congruence,
- To impart the knowledge of encryption and decryption techniques and their applications in managing the security of data.

Course Contents

Unit I

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

Unit II

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,

Unit III

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.

Unit IV
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.

Unit V
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.

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.

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.An Introduction to theory of numbers, 2006, I. Niven, H.S. Zuckerman, H.L. Montgomery, John Wiley & Sons, Inc.

Reference 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, 2nd 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, 5th Ed., 2004, K. Rosen, Addison Wesley.
10. Factorization and Primality Testing, 1989, D. M. Bressoud, Springer-Verlag.
11. A computational introduction to number theory and algebra, 2009, V. Shoup, Cambridge University Press.
12. Mathematics for computer algebra, 1992, M. Mignotte, Springer-Verlag.
13. An introduction to the theory of numbers, 2011, I. Niven, H. S. Zuckerman, H. L. Montgomery, John Wiley.
14. Modern computer algebra, 3rd Ed., 2013, J. Von zur Gathen, J. Gerhard, Cambridge University Press.
15. Introduction to finite fields and their applications, 2012, R. Lidl, H. Niederreiter, Cambridge University Press.
16. Applications of finite fields, 1993, A. J. Menezes, Kluwer Academic Publishers.
17. Rational points on elliptic curves, 2015, J. H. Silverman, J. Tate, Springer International Edition.
18. Guide to elliptic curve cryptography, 2004, D. R. Hankerson, A. J. Menezes, S. A. Vanstone, Springer-Verlag.
19. Public-key cryptography: Theory and practice, 2009, A. Das, C. E. Veni Madhavan, Pearson Education Asia.
20. A course in computational algebraic number theory, 1993, H. Cohen, Springer-Verlag.

Course Code	Course Name	L – T – P	**Credits**
AM 629	**Calculus of Variations and Integral Equations**	3-1-0	**4**

Course Objectives:

- Introduce students to the fundamental concepts and techniques of calculus of variations and integral equations.
- Teach students methods for solving linear integral equations, including Volterra and Fredholm equations, using successive approximation and other iterative techniques.
- Familiarize students with Green's functions and their applications in constructing solutions for non-homogeneous boundary value problems and relating them to integral equations.
- Equip students with the ability to apply calculus of variations to solve motivating problems such as shortest distance, minimum surface area, and geodesics, emphasizing Euler's equation and its applications.

Course Contents

Unit I:

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.

Unit II:

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.

Unit III:

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.

Unit IV:

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.

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.

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, 2nd 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.

Course Code	Course Name	L – T – P	**Credits**
AM 630	**Domain Decomposition Methods for Partial Differential Equations**	3-1-0	**4**

Course Objectives:

- Understand and apply domain decomposition methods to solve partial differential equations (PDEs), focusing on both elliptic and parabolic problems.
- Learn iterative substructuring algorithms, including the Schwarz Method and two-level methods, for efficient solution of discretized PDEs.
- Explore the mathematical foundations of domain decomposition, including variational formulations and stability analysis.
- Extend domain decomposition methods to time-dependent problems and study multilevel and local grid refinement techniques.

Course Contents

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.

Course Outcomes

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

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

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. The 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. Domain Decomposition: Parallel Multilevel Methods for Elliptic Partial Differential Equations, 1996, B. Smith, P. Bjorstad, W. Gropp, Cambridge.

Course Code	Course Name	L – T – P	**Credits**
AM 631	**Multigrid Methods**	3-1-0	**4**

Course Objectives:

- Introduce students to the fundamental concepts of multigrid methods, emphasizing local and global processing techniques.
- Teach students convergence analysis and classical as well as advanced relaxation methods for solving model problems.
- Familiarize students with grid refinement algorithms and Fourier analysis related to convergence behaviors.
- Equip students with the knowledge of handling anisotropic problems and their practical applications using multigrid techniques.

Course Contents

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.

Course Outcomes

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

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.

Text Books

1. A Multigrid Tutorial, 2nd Ed., 2000, E. Henson, and S. F. McCormick, SIAM.
2. Multigrid, 2001, U. Trottenberg, C. W. Oosterlee, A. Schueller, Academic Press.
3. Multigrid Methods, 1982, W. Hackbusch and U. Trottenberg, Springer-Verlag, Berlin.
4. 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.

Course Code	Course Name	L – T – P	**Credits**
AM 632	**Introduction to Non-Newtonian Fluids**	3-1-0	**4**

Course Objectives:

- Introduce students to the fundamental concepts and theoretical foundations of non-Newtonian fluids, including kinematics, governing equations, and constitutive models.
- Equip students with the knowledge to apply non-Newtonian fluid dynamics to practical industrial applications, enhancing their understanding of fluid behavior in complex systems.
- Enable students to analyze and utilize the thermophysical properties of nanofluids to optimize convective heat transport processes in various engineering applications.
- Prepare students to apply their knowledge in selecting appropriate fluids for specific applications such as solar power collection and nuclear waste management, considering the unique characteristics of non-Newtonian fluids.

Course Contents

Unit I: 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.

Unit II: 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.

Unit III: 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.

Unit IV: 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.

Unit V: 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.

Course Outcomes

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

CO1: The applications areas of non-newtonian fluids are broad and this course could help students to apply the theoretical knowledge to the industrial fields

CO2: The thermophysical properties of various nanofluids are utilizes 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 management are very well utilized such nanofluids that fulfil their aim. Thus, this course can help to choose the perfect applicable fluid in these areas

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.

Course Code	Course Name	L – T – P	**Credits**
AM 633	**Bio-Mechanics**	3-1-0	**4**

Course Objectives:

- Introduce students to the principles and mathematical foundations of biomechanics, focusing on tools and methods for investigating biological systems such as blood flow in arteries and the heart.
- Teach students the application of conservation laws (mass, momentum, energy) in biomechanical systems, particularly in the context of blood flow dynamics.
- Familiarize students with the rheological properties of biofluids and their relevance in understanding cardiovascular dynamics.
- Provide students with an understanding of transport phenomena within organ systems, emphasizing applications in biomedical engineering and healthcare.

Course Contents

Unit I: 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.

Unit II: 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

Unit III: The Rheological Properties of Blood Bio-fluid dynamics concept, Transport phenomena and the cardiovascular system.

Unit IV: Biofluid mechanics of organ systems, The lungs, The Kidneys, and the lever. Micro-circulation, Pressure distribution in microvessels, Pressure in the interstitial space, Velocity distribution in microvessels, The velocity-Hemotocrit relationship, mechanics of flow at very low Reynolds numbers.

Course Outcomes

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

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 mass conservation and energy conservation with momentum conservation in the blood flow problems

CO3: Students will learn the Rheological properties of biofluid dynamics concepts

CO4: Students will also learn the transport phenomena and cardiovascular system.

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.

Course Code	Course Name	L – T – P	**Credits**
AM 635	**Finite Elements: Theory and Algorithms**	3-1-0	**4**

Course Objectives:

- To learn basic principles of finite element analysis procedure.
- To learn the theory and characteristics of finite elements that represent engineering structures.
- To learn and apply finite element solutions to structural, thermal, and dynamic problems to develop the knowledge and skills needed to effectively evaluate finite element analyses.

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.

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.

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.

Course Code	Course Name	L – T – P	**Credits**
AM 636	**Cloud Computing**	3-1-0	**4**

Course Objectives:

- To provide students with the fundamentals and essentials of Cloud Computing.
- To provide students with a sound foundation of Cloud Computing so that they can start using and adopting Cloud Computing services and tools in their real-life scenarios.
- To enable students to explore some important cloud computing-driven commercial systems and applications.
- To expose the students to frontier areas of Cloud Computing and information systems, while providing sufficient foundations to enable further study and research.

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 the working platform for CloudSim

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.

Text Books

1. Distributed and Cloud Computing: From Parallel Processing to the Internet of Things, 2011, Kai Hwang, Jack Dongarra and Geoffrey Fox, Morgan Kaufmann.
2. Cloud computing a practical approach, 2010, Anthony T.Velte , 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, Rajkumar Buyya, James Broberg, Andrzej Goscinski, John Wiley & Sons, Inc.

Course Code	Course Name	L – T – P	**Credits**
AM 640	**AI for Medical Image Analysis**	3-0-2	**4**

Course Objectives:

- To solve problems at the interface of computer science, imaging and medicine.
- To explain how digital images are represented, manipulated and processed.
- To apply advanced image processing algorithms to medical images to derive meaningful information.
- To apply supervised and unsupervised machine learning techniques to segment and classify medical images.
- To develop, validate and interpret AI models to gain insight into disease as diagnosed by medical imaging.

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.
Course Outcomes
After completing this course, the students will be able to: **CO1:** Understand different medical imaging modalities **CO2:** Learn the feature extraction schemes specific to imaging modalities **CO3:** Design the applications in line with the requirement of medical imaging **CO4:** Handling the intricacies of medical data and how to address them **CO5:** Propose and develop an AI solution in Medical Imaging using Open-source datasets and custom datasets
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.

Course Code	Course Name	L – T – P	**Credits**
AM 642	**Computer Vision with Pattern Recognition**	3-0-2	**4**

Course Objectives:

- Introduce students to the foundational concepts of computer vision, focusing on conventional feature engineering techniques.
- Familiarize students with standard architectures for object detection and classification in computer vision.
- Equip students with the ability to apply segmentation algorithms across various domains.
- Provide students with practical skills in dataset creation and annotation overview for computer vision applications.
- Enable students to apply computer vision techniques to solve real-world problems in fields such as medical imaging, automation, and autonomous vehicles.

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

Course Outcomes

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

CO1: Understand the concepts of computer vision with conventional feature engineering

CO2: Learn the different standard architectures of object detection and classification

CO3: Perform segmentation algorithms in different domains

CO4: Create the datasets and get an overview of the annotation

CO5: Apply the learned concepts to real-world problems in the area of medical imaging, automation, self-driving cars, etc.

Text Books

1. Computer Vision: Algorithms and Applications, 2nd Ed., 2022, Richard Szeliski, Springer.
2. Digital Image Processing, 4th Ed., 2017, Rafael C Gonzalez and Richard E Woods, Pearson.

Reference Books

1. Computer Vision: Models, Learning, and Inferences, 1st Ed., 2012, Simon J D Prince, Cambridge University.
2. M. Pattern Recognition and Machine Learning, 2006, Christopher Bishop, Springer.
3. Deep Learning, 2016, Ian Goodfellow, Yoshua Bengio, Aaron Courville, MIT Press.

Department Applied Physics

M. Tech. in Sensor Technology

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 flavour. 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.

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 B. E./ B. Tech (all disciplines)

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

PEO1: The M Tech in Sensor Technology programme aims at developing skilled human resources in the field of sensor development, control system design, wireless sensor network, artificial intelligence, machine learning etc 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 Technology Systemsand competitively work towardsthe development of the latest technology in line with national programmes like Make in India.

PROGRAMME 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's program

PO4: Having adaptive thinking and adaptability in relation to environmental context and sustainable development

PO5: Having a clear understanding of professional and ethical responsibility

PO6: Having good cognitive load management skills related to project management and finance

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Tech. (Sensor Technology) the programme, graduates will be able to

PSO1: The MTech Sensor Technology aims at developing a skilled knowledgeable Human task force in the field of Sensor Technology catering to 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 Tech course the students develop an ability to carry out independent research in the area of sensors.

PSO2: The dissertation work of the MTech students leads to publications in high-impact international journals which trains them in technical documentation and report writing.

PSO3: The M Tech Sensor Technology course aims at the development of human resources of high calibre in the field of sensor development, sensor systems, Machine learning, control system and wireless sensors.

Credit Structure

SEMESTER I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	AP 601	Principles of Sensing: Material Science and Physics	3	1	4
2	AP 602	Sensor Data Acquisition systems	3	1	4
3	AP 603	Technology and Packaging of MEMS Systems	3	1	4
4	AP 604	Programming for Machine learning	2	2	4
5	AP 605	Sensor Technology Laboratory-I	3	1	4
6	EE 624	Digital system design using FPGA	3	1	4
7	PGC 601	Research Methodology and IPR	2	0	2
			Total	**18**	**26**

SEMESTER II

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	AP 606	Introduction to Sensor Systems	3	1	4
2	AP 607	Sensors and Actuators	3	1	4
3	AP 608	Machine learning techniques for sensor data analytics	2	2	4
4	AP 609	Sensor Technology Laboratory-II	3	1	4
5		Elective I	3	1	4
6		Elective – II	3	1	4

7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	**18**	**6**	**26**

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP 651	M.Tech. Dissertation Phase I	28		14
		Total	**28**		**14**

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP 652	M.Tech. Dissertation Phase II	28		14
		Total	**28**		**14**

List of Electives:

Sr. No.	Course Code	Course
Electives I& II		
1	AP 610	Advanced Sensors
2	AP 611	Sensors for Defence
3	AP 612	Nanotechnology for Advanced Sensors
5	AP 642	THz Devices and Applications
6	EE 614	EMI, EMC, EMP, NEMP design
7	EE 613	Electronic warfare
8	CE 691	Wireless sensor network

Course Code	Course Name	L-T-P	Credits
AP 601	**Principles of Sensing: Material Science and Physics**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Sensors, its types, its properties and characteristics analysis
- To introduces applications of semiconductors and metals
- To enable the students to understand basic concepts of materials science i.e., sensors

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Sensor Classification, Performance and Types, Error Analysis characteristics	6
Unit II:	Structural, electrical and mechanical and thermal properties	6
Unit III	Applications of metals and semiconductors Thermal expansion devices, shape memory alloys, thermocouple, positive temperature coefficient resistor, negative temperature coefficient resistor, bolometers, strain gauges	10
Unit IV	Dielectric, Magnetic and superconducting materials Polarization, frequency response, piezoelectric, pyroelectric, ferroelectric materials, Paramagnetic, diamagnetic, antiferromagnetic, ferromagnetic, ferrimagnetic, superconducting materials	12
Unit V	Applications of Dielectric, Magnetic and superconducting materials Hall effect, magnetoresistance, SQUID	6
Unit VI	Introduction to Fiber optic sensors	6

Course Outcomes

CO-1:	Interpret the concepts static and dynamic characteristics of sensors and use concepts in common methods for converting a physical parameter into an electrical quantity
CO-2:	Analyze the working principle of different materials-based sensors and choose an appropriate sensor comparing different standards and guidelines to make sensitive measurements of physical parameters like pressure, flow, acceleration, etc.
CO-3:	Examine the working mechanism of different types of sensors
CO-4:	Illustrated the practical implementation of using different materials in sensors and create analytical design and development solutions for sensors.
CO-5:	Summarize different applications of different types of materials for sensors and locate different types of sensors used in real life applications and paraphrase their importance

Text Books

1. Sensor Materials by P T Moseley and A J Crocker, IOP Publishing Ltd 1996
2. Handbook of Modern Sensors: physics, designs and applications by Jacob Fraden, Springer (2010).
3. Sensor Technology Handbook by John S Wilson, Elsevier, (2005)

Reference Books

1. Transducers and Instrumentation, DVS Murty, 2nd Edition2013
2. Material Science and Engineering by Raghavan
3. J. P. Dakin and B Culshaw, Optical Fiber Sensors, Vol. 1 & 2, Artech House, Boston and London,1998.

Course Code	Course Name	L-T-P	Credits
AP 602	**Sensor Data Acquisition Systems**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Fundamentals of data Acquisition.
- To introduce the Data loggers, data acquisition boards and signal conditioning.
- To enable the students to understand network data communication and sensor interface demo using Arduino and LabVIEW software

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Fundamentals of Data Acquisition: Essentials of computer interfacing – configuration and structure -interface systems-interface bus.	6
Unit II:	Signal conditioning: Types of signals and signal conditioning, classes of signal conditioning, types of noises (different types) and basics of environmental aspects, shielded and twisted-pair cable, , Different type of signal conditioners-Digital and analog, applications in real systems	8
Unit III	Data Acquisition boards: A/D Boards, Single-ended vs differential signals, Resolution, dynamic range and accuracy of A/D boards, Sampling rate and the Nyquist theorem, Sampling techniques, D/Aboard. Serial and parallel data communication standards	12
Unit IV	Data Loggers: Methods of operation, stand-alone loggers/controller hardware, communications hardware interface, Data acquisition using PCMCIA cards. Device communications, Communication system basics for remote sensor data acquisition., Ethernet & LAN systems.	12
Unit V	Network data communication model for sensor data handling and communication – 7, Communication Protocols Layer Model and TCP/IP Model. Sensor Interface Demos using Arduino Interface and LabView	8

Course Outcomes

CO-1 :	Interpret the concepts of how sensor data requires further processing
CO-2 :	Analyze the working principle of Data Acquisition systems
CO-3 :	Examine the working mechanism of different signal conditioners
CO-4 :	Illustrate the practical implementation of sensor systems connected to a DAS board and programming of microcontroller platform
CO-5 :	Summarize various modes of sensor data integration and acquisition for further controls / displays

Text Books

1. Ramon Pallas-Areny and John G Webster, Sensors and Signal Conditioning, Wiley India Pvt. Ltd., 2 nded.,2012.
2. 2. Maurizio Di Paolo Emilio, Acquisition systems from fundamentals to Applied Design, Springer,2013.
3. Robert H King, "Introduction to Data Acquisition with LabVIEW", McGraw Hill, 2nd ed.,2012

Reference Books

4. John Park and Steve Mackay, Practical Data Acquisition for Instrumentation and Control', Newness publishers,2003.
5. Maurizio Di Paolo Emilio, Data Acquisition systems- from fundamentals to Applied Design, Springer,2013. 6. Robert H King

Course Code	Course Name	L-T-P	Credits
AP 603	**Technology and Packaging of MEMS systems**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Microsystems and microelectronics
- To introduce the basic of materials, science and engineering of microsystem
- To enable the students to understand working principles of microsystems and its packaging.

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**Evolution of Microsystems:** Concept & History of Micro systems & MEMS, Benefits of Micro Systems, Comparison between Microsystems & microelectronics, Multidisciplinary nature of microsystems development.	**2**
Unit II:	**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.	**4**
Unit III	**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	**8**
Unit IV	**Fabrication of Microsystems**: Photolithography, Ion Implantation, Diffusion, Oxidation, chemical & physical vapor deposition, Epitaxial growth of films, Chemical etching, Plasma etching.	**8**
Unit V	**Micromachining processes:** Bulk Micromachining**,** Surface Micromachining, The LIGA Process.	**4**
Unit VI	**Working principles of microsystems:** Microsensors: Acoustics wave sensors, Biomedical & Bio sensors, Chemical Sensors, Optical Sensors, Pressure Sensors, Thermal Sensors. MEMS with Microactuators: Microgripper, Micromotors, Micro valves, Micro pumps, Micro accelerometer Microfluidics	**8**
Unit VII	**Microsystem packaging:** Levels in microsystem packaging, Interfaces in Microsystem packaging, Essential packaging technologies, 3-d Packaging, assembly of Microsystems. Multi User MEMS Program (MUMPs)	**4**

Lab Assignments		Hrs
Lab 1	To study the etching process in silicon	4
Lab 2	Thin film deposition and analysis	4
Lab 3	3D Printing	4

Course Outcomes	
CO-1 :	Students to be able to understand concepts involved in MEMS
CO-2 :	Students to understand the technologies involved in MEMS fabrication and packaging, their advantages and limitations
CO-3 :	Students to be able to understand working principles in micro sensors and actuators
CO-4 :	Students to become capable of conceptualizing the design of a microsystem

Text Books

1]Tai-Ran Hsu, 'MEMS & Microsystem, Design and Manufacture', McGraw Hill, 2012
2] Physics of Semiconductor Devices by S.M. Sze, Wiley Publications (2006)
3] Mark J Jackson, Micro and Nano-manufacturing, Springer; First Edition, (2006) ISBN

Reference Books

4] Zheng Cui,Micro-nanofabrication: Technologies and Applications, Springer First Edition (2006),ISBN-10:3540289224
5] R. Kassing, P. Petkov,W.Kulish, C. Popov., Functional Properties of Nanostructured Materials. Springer (ISBN: 978-1-4020-4595-0 (Print) 978-1-4020-4594- 3(Online)

Course Code	Course Name	L-T-P	Credits
AP 604	**Programming for Machine learning**	**2-0-2**	**4**

Course Objectives:

- To impart knowledge of programming, its structure types.
- To introduce the python and simple numerical programs
- To enable the students to understand basic of data structures and do object-oriented programming

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Introduction to Python & Simple Numerical Programs Installing Python and Python IDEs, Basic elements of Python, Variables and assignment, branching programs, strings and input, loops, Simple codes, approximate solutions, Floats, Newton–Raphson	12
Unit II:	Functions, scoping, and abstraction Functions, Scoping, Using functions to modularize code, Functions as objects,	6
Unit III	Structured types and mutability Ranges and iterables, Strings, Tuples, Ranges, and Lists, SETS, Dictionaries	6
Unit IV	Recursion, global variables, modules and files, classes Fibonacci Numbers, Palindromes, Global Variables, modules, files, testing and debugging, Abstract data types and classes, some important complexity classes	12
Unit V	Object-oriented programming, algorithms, data structures, Plotting Search algorithms, sorting algorithms, Matplotlib	10

Course Outcomes	
CO-1 :	Learn a language, Python, for expressing computations
CO-2 :	Develop an informal understanding of computational complexity

CO-3 :	Examine the process of moving from an ambiguous problem statement to a computational formulation of a method for solving the problem
CO-4 :	Illustrate the useful set of algorithmic and problem reduction techniques
CO-5 :	Use computational tools (including simple statistical, visualization, and machine learning tools) to model and understand data

Text Books

1. Introduction to Computation and Programming Using Python, by John V Guttag, MIT Press
2. Head-First Python, 2nd edition Paul Barry ***(O'Reilly, 2016)***

Reference Books

1. Learning Python, 5th Edition, by Mark Lutz, Released June 2013Publisher(s): O'Reilly Media, Inc

Course Code	Course Name	L-T-P	Credits
EE 624	**Digital system design using FPGA**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of circuit design techniques.
- To introduce the IIVHDL basics and test pattern generation of algorithms
- To enable the students to understand design of communication modules.

Course Contents

Units	Syllabus Details	Hrs
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.	12
Unit II:	**IIVHDL basics and computation module designs:** Introduction to VHDL - Behavioural modelling - Data flow modelling - Structural modelling - 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.	6
Unit III	**Fault modelling, detection and test pattern generation algorithms:** Introduction to testing – Faults in Digital Circuits – Modelling of faults – Logical Fault Models – Fault detection – Fault Location – Fault	6

	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:** Sensor's 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 - relay/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	12
Unit V	**Contemporary designs and solutions:** Design of data path components, Control path components - Design of a simple RISC CPU - Debugging using Embedded Logic Analysers - 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.	10

LIST OF EXPERIMENTS:

SL No	NAME OF EXPERIMENTS
01.	The Basic FPGA Design Flow 1. To understand use of Xilinx ISE 2. To understand Xilinx Synthesis Technology or XST. 3. Familiarization of Xilinx Vivado Design Tools.
02.	Familiarization of FPGA Boards 1. Xilinx FPGA Boards (Virtex 6, Kintex7) 2.Implementation of Full adder, ALU, Memory and FIFO on FPGA
03.	Fault Detection Logic Implementation on FPGA 1. Stuck at Fault 2. Memory BIST
04.	Implementation of RISC CPU on FPGA and debugging using Embedded Logic Analysers.

Course Outcomes

CO-1:	Familiarized with the design of Combinational and Synchronous and Asynchronous Sequential Circuits. Gave an Overview of PLDs and PALs
CO-2:	Covered basic introduction of VHDL and the basic language elements. Various Combinational and Sequential circuits were designed using VHDL
CO-3:	In-depth analysis of Faults and testability in digital systems including modelling and detection

CO-4:	Interfacing various sensors and reading/writing to/from various file formats. Implementing various modulation schemes
CO-5:	Design of a RISC CPU, data and control path components. Introduction to various floating/fractional/fixed-point arithmetic operations. Implementing Data encryption/Decryption system, Error correction, communication modules, BERT

Text 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 Modelling of Digital Systems", McGraw-Hill, 1998

Reference Books

1. Digital Circuits and Logic Design – Samuel C. Lee, PHI
2. Smith, "Application Specific Integrated Circuits", Addison-Wesley, 1997
3. P.K. Lala, "Digital Circuit Testing and Testability", Academic Press, 2002

Course Code	Course Name	L-T-P	Credits
AP 605	**Sensor Technology Laboratory-I**	**3-0-1**	**4**

Course Objectives:

- To impart hands on knowledge of basic sensor experiments.
- To introduce the experimental approach of subject.
- To enable the students to understand the hands-on experience of various science concepts.

Course Contents

Units	Syllabus Details
Unit I:	Determination of various parameters of optical fiber, Micro and Macro bending for strain detection Michelson Interferometry
Unit II:	Hall effect experiment Resistive sensors
Unit III	Automation of sensor system, Humidity Sensor, Temperature Sensor
Unit IV	Ultrasonic proximity sensor, temperature sensors
Unit V	LabVIEW based automation
	Sensor Calibration Vibration Sensors GM Counter

Course Outcomes

CO-1:	Interpret the concepts of basic physics behind several sensors
CO-2:	Analyze optical, electrical, thermal properties
CO-3:	Examine situations where the sensors based on above properties can be used
CO-4:	Illustrate implementation of sensor system on LabView
CO-5:	Summarize different applications where the sensors systems can be used

Text Books

Reference Books

Course Code	Course Name	L-T-P	Credits
AP 606	**Introduction to Sensor Systems**	**3-0-1**	**4**

Course Objectives:

- To impart hands on knowledge of basic sensor systems.
- To introduce the various type of sensors and its basic concepts.
- To enable the students to understand basic concepts behind sensors and sensor systems.

Course Contents

Units Divisions	Syllabus Details
Unit I:	Mechanical and electromechanical sensors: Resistive potentiometer, strain gauge, inductive sensor, capacitive sensor
Unit II:	Magnetic sensors: Magneto-resistive, Hall effect sensors, Inductance and eddy current sensors, LVDT, RVDT
Unit III	Pressure measurement: manometer, ring balance manometer, bell type manometer, thin plate diaphragms, bellows, bourdon tube, piezo-resistive and capacitive pressure sensor, optoelectronic pressure sensors, vacuum sensors- Pirani gauge, ionization gage, gas drag gauge.
Unit IV	Force and torque measurement: helical spiral springs, cantilever, beams, diaphragm, load cell, torsion bar, flat spiral spring for torque
Unit V	Position and displacement, Velocity and Acceleration sensors: Electromagnetic velocity sensor, Doppler with sound or light or other EM wave, Accelerometer characteristics, capacitive, piezo- resistive, piezoelectric accelerometer, thermal accelerometer, rotor, monolithic and optical gyroscopes and mechanical gyroscopes.

Course Outcomes

CO-1:	Interpret the concepts of mechanical and electromechanical sensors
CO-2:	Analyze the working principle of magnetic sensors
CO-3:	Examine the working mechanism of different types of sensors
CO-4:	Illustrated the practical implementation pressure sensing.
CO-5:	Summarize different applications of above types of sensors for position, velocity and acceleration measurement

Text Books

1]The measurement, Instrumentation and Sensors Handbook, Editor, John, G Webster, CRC Press, 1999.
2]Rangan Sharma, Instrumentation, Devices and Systems, Tata McGraw Hill, Second Edition

Reference Books
1] Sensors and Transducers, D Patranabis PHI Publications, 2nd edition (2013).

Course Code	Course Name	L-T-P	Credits
AP 607	**Sensors and Actuators**	**3-0-1**	**4**

Course Objectives:

- To impart the knowledge of optical components, sources and detectors.
- To introduce the various type of detectors, sensors and actuators.
- To enable the students to understand basic concepts of sensors, detectors and actuators

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Optical properties, components, sources and detectors: types of sources: source- detector characteristics, Radiometry, Photometry, windows, mirrors, lenses, Fresnel lenses	4
Unit II:	Light Detectors: Photoconductive detectors, Photo diodes, Avalanche photodiodes, Photoresistors, Photo multipliers, CCDs, Image Intensifiers, Solar Cells, photon counting techniques to count low photon flux, Thermal detectors: Golay Cells, Thermopile Sensors, Pyroelectric Sensors, Bolometers, Active FIR Sensors, Gas Flame detectors	6
Unit III	Radiation Detectors: Scintillation detectors, Ionization Detectors: Ionization Chambers, Proportional Chambers, Geiger-Muller Counters, Semiconductor Detectors	4
Unit IV	Temperature Sensors: Thermo resistive Sensors, Thermoelectric Contact Semiconductor Junction Sensors, Optical Temperature Sensors, Acoustic Temperature Sensors, Piezoelectric Temperature Sensors	6
Unit V	Chemical Sensors: Classification of Chemical Sensing Mechanisms, Direct Sensors: MOX, Chem Fet, Electrochemical, Complex Sensors: Thermal, Pellister Catalytic, Mass detector, Biochemical and enzyme Sensors, Smart chemical sensors, Mass Spectroscopy	6
Unit VI	Actuation and actuators: Active elements: Piezoelectric, magneto-strictive, photoelectric, thermoelectric, actuator principles, actuators as system components, actuators in mechatronics and adaptronics, electrostatic/Electromagnetic actuators (types of motors) Introduction and classification of motors, PZT actuators, Smart actuators, multilayer actuator.	8

Lab Assignments		hrs
Lab 1	Comparative experimental study of different Temperature Sensors	4
Lab 2	Stepper motor control experiment	4
Lab 3	Demo of Radiation detector	4
Lab 4	COMSOL Multiphysics designing	4

Course Outcomes

CO-1:	Students to learn the working principles of sensors and actuators

CO-2:	Students to be able to understand and carry out applications-based selection of sensors and actuators
CO-3:	Students to become capable of characterizing a particular given sensor

Text Books

1]Handbook of Modern Sensors: Physics, Designs and Applications, Jacob Fraden, Third Edition, Springer

2] Micromachined Transducers Sourcebook," G.T.A. Kovacs, McGraw Hill,1998.

Reference Books

1] Actuator's basics and applications, H Janocha, Springer.

2] Sensors and Transducers, D Patranabis PHI Publications, 2nd edition (2013).

Course Code	Course Name	L-T-P	Credits
AP 608	**Machine Learning techniques for Sensor Data Analytics**	**2-0-2**	**4**

Course Objectives:

- To impart the knowledge of machine learning techniques.
- To introduce the sensor data analytics, ML examples and ML type of learning
- To enable the students to understand & solve issues with machine learning techniques

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Introduction: Role of Machine learning techniques in sensor data analytics, Learning from data, Machine learning examples, Simple model for Machine Learning, Types of learning,	6
Unit II:	Theory of generalization: Feasibility of learning, Hoeffding inequality, complexity of hypothesis set, growth function, VC dimension, Training versus testing	6
Unit III	Supervised Learning: Perceptron, Linear classification, Linear regression, Logistic regression, Neural Network, Backpropagation algorithm, Support Vector Machines, Radial Basis Functions, K-nearest neighbour, Decision Trees, Bayesian Learning, Deep learning, Feature extraction and dimensionality reduction: Curse of dimensionality, Principal Component analysis, Linear discriminant analysis	12
Unit IV	Unsupervised Learning: Clustering, K-means clustering, hierarchical clustering	10
Unit V	Machine Learning issues: Overfitting, Validation, Occam's razor, Agglomerative Sampling bias, Data Snooping	10

Course Outcomes

CO-1:	Interpret the concepts machine learning
CO-2:	Analyze different types of machine learning techniques
CO-3:	Examine situations where supervised learning can be used
CO-4:	Illustrate implementation of supervised and unsupervised learning.
CO-5:	Summarize different applications of machine learning techniques in sensors

Text Books

1. Thomas A. Runkler, "Data Analytics: Models and Algorithms for Intelligent Data Analysis", Springer Vieweg,2012.

2. S. Haykin, “Neural Networks, A Comprehensive Foundation “, Pearson Education Inc.,2004.
3. Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification, 2nd Edition,2001

Reference Books

1. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer,2006.
2. Y. S. Abu-Mostafa, M. Magdon-Ismail, and Hsuan-Tien Lin, Learning from data, AMLbook.com
3. Y. S. Abu-Mostafa, Learning from data, Caltech lectures(online),
4. S. Sarkar, Introduction to Machine Learning, NPTEL course, IIT Kharagpur(online).

Course Code	Course Name	L-T-P	Credits
AP 609	**Sensor Technology Laboratory- II**	**3-0-1**	**4**

Course Objectives:

- To impart hands on knowledge of basic sensor experiments.
- To introduce the experimental approach of subject.
- To enable the students to understand the hands-on experience of various science concepts.

Course Contents

Units	Syllabus Details
Unit I:	Basic experiments with Raspberry Pi Smart Irrigation System
Unit II:	Modulation of the digital signal using Raspberry Pi 1. PWM generation 2. Changing the PWM parameters
Unit III	Interfacing and displaying the sensor on output LCD screen to show temperature and humidity Demonstration of Internet of Things
Unit IV	1. Data collecting and Data logging on a PC using Raspberry Pi 2. To control the actuator using RPi Servo motor 3. Interconnecting sensor and actuator using RPi
Unit V	1. Operating Joystick using RPi and ATMEGA microcontroller 2. Controlling servo motor using joystick through RPi and ATMEGA
Unit VI	FPGA based experiments Implementation Gate Circuits Sequential Circuits (Finite State Machine)

	Counters UART communication with PC

Lab Assignments	
Lab 1	Mini project from what has been learned in the lab

Course Outcomes

CO-1:	Interpret the basic concepts of microcomputer
CO-2:	Analyze different types of microcomputers
CO-3:	Examine situations where they can be used
CO-4:	Illustrate implementation of sensor system using Raspberry Pi
CO-5:	Summarize different applications of microcomputer in real rife

Text Books

Reference Books

Course Code	Course Name	L-T-P	Credits
AP 610	**Advanced Sensors**	**3-0-1**	**4**

Course Objectives:

- To impart the knowledge of sensors systems
- To introduce the working of different sensor system in various applications
- To enable the students to understand the application of sensors in various fields.

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**Sensor systems for nuclear applications:** Experimental investigation of interactions of radiation with matter. Principles and mechanisms underlying nuclear radiation detection and measurements; operation of nuclear electronic laboratory instrumentation; application of gas-filled, scintillation and semiconductor laboratory detectors for measurement of alpha, beta, gamma, and neutron radiation.	**9**
Unit II:	**Sensors in Automotive Applications:** Introduction to Automotive Engineering, Power train Sensors, Sensors for Chassis management, Sensors for vehicle body management, Sensors for automotive vehicle convenience, Air Bag and Seat Belt Pre tensioner Systems, Passenger Convenience Systems, Modern Trends	**9**
Unit III	**Sensors in Biomedical Applications:** Physical Sensors in Biomedicine, Electrochemical Sensors, EEG, EMG & ECG, Detectors in Radiology, Sound in Medicine, Amperometric Biosensor, Potentiometric Biosensor, Optical Biosensor, Immunosensors, Hybrid Biosensor, In Vivo Biosensor and Commercial Biosensor, Demonstration of NMR, PET MRI	**9**
Unit IV	**Sensors in Environmental Applications:** Measurement techniques for water quality, Measurement techniques for chemical Pollutants, Waste water treatment, Air pollution; Its sources, Measurement techniques for air quality,	**8**

	Sensors in exhaust gas treatment	
Unit V	**Metamaterial based sensors,** refractive index sensors, strain sensing, pressure and temperature sensing, Wearable and implantable sensors	**8**
Unit VI	Night vision devices, Portable and /or wearable inertial and position, motion and acceleration sensors. Miniaturised and highly sensitive vision camera system	8

Course Outcomes

CO-1:	To make students learn the concepts of advanced sensors that are used in various applications.
CO-2:	Demonstrate the applications of these sensors practically
CO-3:	Perform some real-time applications using advanced sensor system
CO-4:	To understand sensors used in systems
CO-5:	To know the recent advanced sensors

Text Books

1. Medical Instrumentation; Application and Design; J. G. Webster, Editor, 4th Edition,2015, JohnWiley&Sons, Inc.; New York.
2. John Turner, Automotive Sensors, Momentum Press, 1st Edition,2009.
3. Automotive Sensors, BOSCH,2002

Reference Books

1. Techniques of Radiation Dosimetry by K. Mahesh1985
2. Nuclear Radiation Detectors, S.S. Kapoor, V. S. Ramamurthy1986
3. Handbook Of Chemical and Biological Sensors R.F Taylor, Jerome S. Schultz, 1996 by CRCPress

Course Code	Course Name	L-T-P	Credits
AP 611	**Sensors for Defence**	**3-0-1**	**4**

Course Objectives:

- To impart the knowledge of sensors used in defence applications
- To introduce the working of sensors in defence system
- To enable the students to understand the design and basics of sensors in defence applications

Course Contents

Units	Syllabus Details	Hrs
Unit I:	(Micro) µ radar for personnel use and for unmanned miniaturized vehicles, SAR, GPR principles.	8
Unit II:	Health monitoring sensors (embedded, continuous or intelligent), Condition monitoring of equipment and munitions. Drug and nutraceutical (nutrition) delivery sensors and systems. Wireless body area network	10
Unit III	Sonar sensors Ultrasonic sensors, measurements for anemometers, tank or channel level, and speed through air or water, Robot sonars, counter measures, active sonar systems, sonars for military applications, antisubmarine warfare, submarine navigation, intercept sonar.	10
Unit IV	Extra Low Frequency Electromagnetic (ELFE) sensors **(**sensors for 3-30 Hz, requirements of such sensors, submarine applications, underwater	10

	communications, other applications such as pipeline gauges, ham radio, night vision), Star-Sensors	
Unit V	Hyperspectral imaging and multi-sensor data fusion and I-STAR (MW, SW, LW), weapon systems for UAV, smart sensors for long range acquisition and long-range laser designation, seekers EO, Laser, IR, UV, cameras miniaturize for DRONE. Emerging technology in defence sensor design and testing (can be covered by experts in the field)	8

Course Outcomes

CO-1:	To make students understand the importance of sensors for various defence applicati
CO-2:	To interpret the working of a variety of sensors that are useful in Defence
CO-3:	Illustrate implementation of sensor in various apparatus that are used in defence
CO-4 :	Summarize different applications of sensors in defence
CO-5:	Summarize different applications nanostructures for sensors

Text Books

1. K. Biggs, M. Burris, M. Stanley, The Complete Guide to Night Vision Paperback, CreateSpace Independent Publishing Platform,2014.
2. Inputs from DRDO scientists working in the relevant field.
3. Research papers: Wolf, S., J. Davis, and M. Nesenoff. "Superconducting extremely low frequency (ELF) magnetic field sensors for submarine communications." *IEEE Transactions on Communications* 22.4 (1974):549-554.

Reference Books

1. Constable, Steven, and Leonard J. Srnka. "An introduction to marine controlled-source electromagnetic methods for hydrocarbon exploration." *Geophysics* 72.2 (2007): WA3-WA12.
2. McKerrow, P. J. "Robot perception with ultrasonic sensors using data fusion." *Systems, Man and Cybernetics, 1995. Intelligent Systems for the 21st Century., IEEE International Conference on*. Vol 2. IEEE,1995.
3. Staszewski, Wieslaw, ChrBoller, and Geoffrey R. Tomlinson, eds. *Health monitoring of aerospace structures: smart sensor technologies and signal processing*. John Wiley & Sons, 2004

Course Code	Course Name	L-T-P	Credits
AP 612	**Nanotechnology for Advanced Sensors**	**3-0-1**	**4**

Course Objectives:

- To impart the knowledge of nanotechnology used in sensors
- To introduce concepts of nanostructures, nanoscale phenomenon & nano sensors
- To enable the students to understand the working principles of nanotechnology used in sensors.

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Implications of nano size on physical and chemical properties: Density of States, 2D, 1D, 0D, Quantum size effect, large surface to volume ratio, surface functionalization, Physical Chemistry of solid surfaces, crystal structures, surface energy, chemical potential	8
Unit II:	Fundamentals of nucleation and growth: Electrostatic Stabilization Surface charge density, Electric potential at the proximity of solid surface, Van der	8

	Waals attraction potential, Interactions between two particles: DLVO theory, Solvent and polymer, Interactions between polymer layers, Mixed steric and electric interactions	
Unit III	Nanoscale Phenomenon: Nanoparticles, nano-clusters, nanotubes, nanowires and nanodots. Electronic structure: quantum dots, quantum wires and quantum wells, confinement of electrons energy quantization, semiconductor nanocrystals, carbon nanotubes, quantum wells.	8
Unit IV	Characterization and properties of nanomaterials: Structural Characterization, X-ray diffraction (XRD), Small angle X-ray scattering (SAXS), Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Scanning probe microscopy (SPM), Surface plasmon resonance	9
Unit V	Nano Sensors: Metal nanoparticle-based Sensors, Quantum Dot, Nanowire-based Sensors, Carbon Nanotubes-based Sensors, Sensors Based on Nanostructures of Metal Oxide, Mass-Sensitive Nano sensors, Arrays of Nanomaterial-based Sensors, e-nose	12

Course Outcomes

CO-1:	Interpret basic concepts of nanotechnology
CO-2:	Analyze growth of nanostructures
CO-3:	Examine different types of nanostructures and their characterization
CO-4:	Illustrate implementation of nanostructures for exploring different properties
CO-5:	Summarize different applications nanostructures for sensors

Text Books

1. Nanostructures & nanomaterials Synthesis, Properties & Applications, Guozhong Cao, Imperial College Press (2004).
2. Introduction to Nanotechnology, Charles Poole Jr and Frank J Owens, Wiley India, New Delhi (2006)
3. Nanophysics and Nanotechnology, Edward L Wolf, Wiley-VCH, Verlag (2006)

Reference Books

1. Ramsden Jeremy, Nanotechnology, an Introduction. Elsevier (2011).
2. Florinel-Gabriel Banica, Chemical Sensors and Biosensors: Fundamentals and Applications, John Wiley and Sons (2012)

M. Tech. in Lasers and Electro-optics

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 Master degree or equivalent in Physics, Applied Physics, Engineering Physics, Electronic Science, Photonics, Optics, Material Science, Instrumentation Science or any equivalent branch

OR

B. E./ B. Tech (Any discipline)

Organization: The M. Tech. Programme is of four-semester duration. In each of the first two 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. 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 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 Tech in Lasers and Electro-Optics programme aims at developing skilled human resources in the field of Optics, lasers and Electro-optics. 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: 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's program

PO4: Having adaptive thinking and adaptability in relation to environmental context and sustainable development

PO5: Having a clear understanding of professional and ethical responsibility

PO6: Having a good cognitive load management skill related to project management and finance

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Tech. (Lasers and Electro-Optics) programme, graduates will be able to

PSO1: The M. Tech in Lasers and Electro-Optics aims at developing a skilled knowledgeable Human task force in the field of Lasers and Electro-Optics 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. Tech. course, the students develop an ability to carry out independent research in the area of optical devices.

PSO2: The dissertation work of the M. 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. Tech. in Lasers and Electro-Optics course is to generate highly competent human resources in the areas of laser development, electro-optic systems, fibre optics, applied optics, and computational photonics.

Credit Structure

Semester I

Sl No	Course Code	Course Name	Contact Hours/week		Credits
			L	P/T (in Hr)	
1	AP 621	Fundamentals of Lasers and Laser Systems	3	1	4
2	AP 622	Optical Electronics	3	1	4
3	AP 623	Introduction to Fiber Optics	3	1	4
4	AP 624	Semiconductor Photonic devices	3	1	4
5	AP 625	Quantum mechanics for Engineers	3	1	4
6	AP 701	Opto-electronics Laboratory – I	0	8	4
7	PGC 601	Research Methodology and IPR	2	0	2
		TOTAL	**17**	**9**	**26**

Semester II

Sl No	Course Code	Course Name	Contact Hours/week		Credits
			L	P/T (in Hr)	
1	AP 631	Laser Applications	3	1	4
2	AP 632	Computational Photonics	3	1	4
3	AP 702	Opto-electronics Laboratory – II	0	**8**	4
4	AP 6XX	Elective – I	3	1	4
5	AP 6XX	Elective – II	3	1	4
6	AP 6XX	Elective – III	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		TOTAL	**17**	**9**	**26**

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP 651	M. Tech. Dissertation Phase I	28		14
		Total	**28**		**14**

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP 652	M. Tech. Dissertation Phase II	28		14
		Total	**28**		**14**

List of Electives

Sr. No.	Course Code	Course
Elective I,II & III		
1	AP 641	High Power Lasers
2	AP 642	Terahertz Devices and Applications
3	AP 643	Free Space Optical Communication
4	AP 644	Nanophotonics
5	AP 645	Non-linear and Quantum Optics
6	AP 646	Integrated Optics and Silicon Photonics

Course Code	Course Name	L-T-P	Credits
AP 621	**Fundamentals of Lasers and Laser Systems**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of basics of Light & Lasers
- To introduces the theory of laser system and its types.
- To enable the students to understand basic working of laser systems

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Light-matter interaction: Interaction of radiation with atomic systems, Einstein's coefficients, spontaneous emission, stimulated emission, Linewidth of the laser, line broadening	6
Unit II:	Lasers Oscillation: Theory of laser oscillation; Threshold condition, Rate equation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output power, Spectral distribution, Spatial distribution and polarization, Hole burning, Properties of laser beam, Pumping techniques.	12
Unit III	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.	10
Unit IV	Laser Systems 1: Ruby Lasers, Neodymium-Based Lasers, Titanium Sapphire Laser, He–Ne Laser, Argon Ion Laser, CO2 laser, Excimer Laser and Fiber Lasers & Amplifiers.	9
Unit V	Laser Systems 2: Semiconductor Lasers, Optical Gain in Semiconductors, Quantum Well Lasers, Quantum Dot Laser, and Quantum Cascade Laser	9

Course Outcomes

CO-1:	Interpret the concepts of laser technology
CO-2:	Analyze the working principle of lasers
CO-3:	Examine the laser radiation beams
CO-4:	Illustrate and construct the practical laser systems
CO-5:	Summarize different types of laser systems and its working principals

Text Books
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.
Reference Books
1. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988 **2.** P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).

Course Code	Course Name	L-T-P	Credits
AP 622	**Optical Electronics**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Electromagnetic fields, polarization, electro, magneto and acousto-optic.
- To introduces the basic principles of optical electronics
- To enable the students to understand basic of light, electronics and optics

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**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'	**9**
Unit II:	**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: polarizing and non-polarizing, wavelength filters, dichroic mirrors, Lenses.	**12**
Unit III	**Electro-optics:** Basic principles: Pockel and Kerr effects, Electro-optic devices: modulators, switches, and scanners, E.O. effect in liquid crystals; LCDs and SLMs, Applications.	**9**
Unit IV	**Magneto-optics**: Principles, Faraday effect, Gyro tropic permittivity, Kerr rotation and Kerr ellipticity, Applications.	**6**
Unit V	**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. Acousto-optic devices: Modulators, deflectors, scanners, interconnections, and Acousto optic Tunable filters.	**10**

Course Outcomes

CO-1:	Interpret the concepts of optical electronics
CO-2:	Analyze the working principle of ME Theory, EO, MO and AO effects
CO-3:	Examine the working mechanism of different types of Optical components, EO, MO and AO effects
CO-4:	Illustrate the practical use of Optical components, EO, MO and AO effects
CO-5:	Summarize different applications of optical electronics devices

Text Books

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. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
Reference Books
1. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000. 2. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998. 3. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988.

Course Code	Course Name	L-T-P	Credits
AP 623	**Introduction to Fiber Optics**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Optical Fiber, Fiber amplifier, Optical Fiber Sensors.
- To introduces the basic concepts of Fiber optics.
- To enable the students to understand basic of optical fiber communication

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**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.	**12**
Unit II:	**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	**9**
Unit III	**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	**9**
Unit IV	**Optical Fiber Sensors:** Introduction, Classification and Types of Optical Fiber Sensors, Sensor Modulation techniques, Fiber Bragg Grating Sensors: Principle and Applications.	**9**
Unit V	**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.	**9**

Course Outcomes	
CO-1:	Understand the basics concepts of Fiber Optic Communication
CO-2:	Understand all the sub-components of Fiber Optics
CO-3:	Examine the working mechanism of Fiber Optics
CO-4:	Illustrate the practical implementation of Fiber Optic Communication
CO-5:	Summarize different applications of Fiber Optic Communication

Text Books

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

Reference Books

1. J.P. Dakin & B Culshaw, Optical Fiber Sensors, Vol. 1&2., Artech House 1998
2. K.T.V. Grattan & B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, 1988

Course Code	Course Name	L-T-P	Credits
AP 624	**Semiconductor Photonic devices**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Semiconductor physics, semiconductor lasers.
- To introduces the basic concepts of Semiconductors, LEDs and Photodetectors.
- To enable the students to understand basic working of semiconductor photonic devices.

Course Contents

Units	Syllabus Details
Unit I:	**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
Unit II:	**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.
Unit III	**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.
Unit IV	**Modulation and Switching Devices:** Analog and Digital Modulation of light sources, Franz-Keldysh and Stark-effect based Modulators, QW Electro-absorption modulator.
Unit V	**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, Coherent detection. CCDs and PICs.

Course Outcomes	
CO-1:	Understand the basics of Semiconductor Physics
CO-2:	Interpret all the optical properties and processes in semiconductors
CO-3:	Examine the working mechanism of different kinds of LEDs and LASERs
CO-4:	Illustrate the implementation of Modulation and Switching Devices

CO-5:	Explain different types of photodiodes and photodetectors

Text Books

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), 6^{th} Ed., Ch.15-17.

Reference Books

1. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2^{nd} Ed. (2007), Ch.16, 17.
2. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3^{rd} Ed. (2021).
3. Streetman, Ben, and Sanjay Banerjee. Solid state electronic devices. Pearson Higher Ed, 2015.

Course Code	Course Name	L-T-P	Credits
AP 625	**Quantum mechanics for Engineers**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of concepts of quantum mechanics.
- To introduces the basic principles 1 electron atom, quantum number, quantum statistics.
- To enable the students to understand basic of quantum mechanics to lasers

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Introduction: Thermal radiation, Plank's postulates, The Schrödinger equation, Statistical interpretation, probability, normalization, momentum, the uncertainty principle	**9**
Unit II:	Time Independent Schrödinger: stationary states, infinite square well, harmonic oscillator, free particle, delta function potential, finite square well	**9**
Unit III	Formalism: Hilbert's space, observables, eigen function of Hermitian operator, statistical interpretation, Dirac notation	**9**
Unit IV	One electron atom: solution of Schrödinger equation in 3D, eigen values, quantum numbers, and degeneracy, orbital angular	**9**
Unit V	Quantum statistics: indistinguishability and quantum statistics, quantum distribution functions, Boltzmann distribution as an approximation to quantum distributions, The Lasers	**9**

Course Outcomes

CO-1:	Understand the basic concepts of quantum mechanics Physics
CO-2:	Interpret the physical meaning of formulation in quantum mechanics
CO-3:	Examine different 1D problems in quantum mechanics
CO-4:	Illustrate the implementation to 1 electron atoms
CO-5:	Explain Quantum mechanics to Lasers

Text Books

1. Beiser, Arthur. Concepts of modern physics. 2003.
2. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing
3. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing

Reference Books

1. Quantum Mechanics by B H Bransden and C J Joachain Pearson Publishing

2. Zettili, Nouredine. "Quantum mechanics: concepts and applications." John Wiley and Sons, Ltd., Publishing 2nd Ed. (2009).

Course Code	Course Name	L-T-P	Credits
AP 631	**Laser Applications**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Laser applications.
- To introduces the Holography, Laser Metrology and Laser Spectroscopy
- To enable the students to understand Industrial and defence applications

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**Laser Metrology: Laser** for measurement of distance, length, velocity, acceleration; rotation sensing; RLG and FOG.	**6**
Unit II:	**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**
Unit III	**Holography:** Holographic interferometry and applications; Holography for non – destructive testing – Holographic components	**6**
Unit IV	**Industrial Application of Laser:** Laser cutting, Laser welding, Laser drilling, Laser marking, Photolithography, Laser-based unmanned ground vehicles	**9**
Unit V	**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	**12**

Course Outcomes

CO-1:	Familiarize to a variety of applications on lasers
CO-2:	Interpret how laser-based metrological techniques work
CO-3:	Understand laser spectroscopy applications
CO-4:	Investigate various methods of how a laser can be used for defence applications
CO-5:	Summarize different applications of lasers

Text Books

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 Books

1. K. Bharat, Laser Safety Tools and Training, CRC Press 2009
2. K. Nagothu, New Paradigms for Underwater Communication, ProQuest 2009

Course Code	Course Name	L-T-P	Credits
AP 632	**Computational Photonics**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Simulation, Modelling of photonics devices
- To introduces the various method of computational photonics
- To enable the students to understand Fiber Optics Modelling and nano design

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**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, plasmonic and microwave waveguides,	**12**
Unit II:	**Beam Propagation Method:** Theory and working of beam propagation method, Tutorials on MMI couplers, optical gratings, co-directional couplers or polarization converters.	**9**
Unit III	**FDTD Method:** Theory and working of FDTD method, Tutorials on photonics band gap simulation: 2D and 3D of different crystal lattices.	**9**
Unit IV	**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	**9**
Unit V	**Nano-design:** Mask designing for nanofabrication of different device geometry	**6**

Course Outcomes

CO-1:	Interpret the concepts of Simulation and Modelling methodology
CO-2:	Analyse the modelling results of photonics devices
CO-3:	Examine the working photonics devices with different methods
CO-4:	Demonstrate the practical implementation
CO-5:	Understand the nanofabrication

Text Books

1. S. Sujecki, Photonics Modelling and Design, CRC Press, 2015.

2. K. Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2000

Reference Books

1. A. Taflove, Computational Electrodynamics: The Finite-Difference Time Domain Method. Norwood, MA: Artech House, 1995.

Course Code	Course Name	L-T-P	Credits
AP 641	**High Power Lasers**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of High-Power Lasers Technology
- To introduce the HPLS, HP Fiber Laser and Amplifiers, Beam Director technology.
- To enable the students to understand working mechanism of High-Power Lasers.

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**High Power Lasers Source:** Criteria for High Power Capability, High Power Laser Resonators and Beam Quality Considerations, High Power Lasers: HF, DF, COIL, CO_2 Gas Dynamic Laser, Alkali Laser, High-Power Solid-State Laser, Free electron laser (FEL), HPL beam combining techniques, Thermal management.	**9**
Unit II:	**High Power Fiber Laser and Amplifiers:** Introduction, Materials, Fiber design, Fiber laser components, High Power Pulse Fiber Lasers, High Power cw Fiber Laser Systems, High Energy ns and fs Fiber Laser Systems, Mode-Locked fs Fiber Lasers, Single Frequency Fiber Lasers, Beam Combining.	**9**
Unit III	**Beam Director Technology**: Design considerations for beam director, threat alerting system, target acquisition & tracking system, laser beam pointing, target sightline stabilization, system processor & boresight functions, HPL beam control, battle damage assessment, Effects of atmosphere on HPL beam propagation; Adaptive optics	**9**
Unit IV	Applications to protect against military threats: laser protection from missiles, laser to address threat of new nuclear weapons, protecting assets from directed energy lasers, lidar protects from chemical/biological weapons	**9**
Unit V	**Safety aspects of laser & legislation:** Effective laser safety, laser safety standards; hazard classification of lasers, maximum permissible exposure (MPE), hazard distances, zones, calculation of NOHD; Potential hazard to personnel: eye anatomy & hazards, hazards to skin, other potential hazards (non-beam hazards; common causes of laser incidents; safety operating guidelines/procedures; field testing & planning, range laser safety officer; Legislation: Protocol IV.	**12**

Course Outcomes

CO-1:	Interpret the concepts of HPL technology
CO-2:	Analyze the working principle of different types of HPLs
CO-3:	Examine the working mechanism of High Power Fiber Lasers
CO-4:	Demonstrate the practical implementation of HPLs
CO-5:	Understand the Safety & legislations related to HPL

Text Books	
1.	High Power Lasers–Directed Energy Weapons Impact on Defence and Security, A. Mallik, DRDO MONOGRAPHS/SPECIAL PUBLICATIONS SERIES, 2012
2.	H. Injeyan and G. Goodno, High Power Laser Handbook, McGraw-Hill Professional; 1 edition (April 25, 2011)
3.	AK Jha, Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, Wiley, 2000
4.	Ter-Mikirtychev and Vartan, Fundamentals of fiber lasers and fiber amplifiers, Springer Series in Optical Sciences, Vol. 181, 2014.

Reference Books	
1.	B. Zohuri, Directed Energy Weapons Technologies, CRC Press, 1 ed., 2012.
2.	V VApollonov, High-Power Optics: Lasers and Applications, Springer International Publishing, Switzerland, 2015
3.	Alastair D. McAulay, MILITARY LASER TECHNOLOGY FOR DEFENSE: Technology for Revolutionizing 21st Century Warfare, John Wiley & Sons, Singapore, 2011

Course Code	Course Name	L-T-P	Credits
AP 642	**Terahertz Devices and Applications**	**3-0-1**	**4**

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 Contents

Units	Syllabus Details	Hrs
Unit I:	**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	**9**
Unit II:	**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	**9**
Unit III	**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	**9**
Unit IV	**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.	**9**

Unit V	**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	**9**

Course Outcomes

CO-1:	Interpret the concepts of terahertz technology
CO-2:	Analyze the working principle of different types of terahertz signal sources
CO-3:	Examine the working mechanism of different types of terahertz detectors
CO-4:	Illustrate the practical implementation of fabrication of components and circuits for terahertz systems
CO-5:	Summarize different applications of terahertz technology for imaging, sensing and communications

Text Books

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 Books

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.

Course Code	Course Name	L-T-P	Credits
AP 643	**Free Space Optical Communications**	**3-0-1**	**4**

Course Objectives:

- To impart basic knowledge of FSOC
- To introduce the basic techniques of Modelling, Mitigation techniques, Laser beam Tracking, pointing & acquisition.
- To enable the students to understand different application of FSOC.

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**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.	**9**
Unit II:	**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**
Unit III	**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	**12**

	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	
Unit IV	**Mitigation techniques:** introduction, aperture averaging, various diversity techniques, spatial diversity, time diversity coding techniques, adaptive optics and other techniques.	**9**
Unit V	**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**

Course Outcomes

CO-1:	Interpret the concepts of Free Space Optical Communication
CO-2:	Understand all the sub-components
CO-3:	Examine the working mechanism of FSOC
CO-4:	Illustrate the practical implementation of FSOC
CO-5:	Summarize different applications of FSOC such as VLC/UWOC

Text Books

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 Books

1. Morris Katzman, Laser Satellite Communications. Prentice Hall Inc 1991
2. Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, A.K. Jha

Course Code	Course Name	L-T-P	Credits
AP 644	**Nanophotonics**	**3-0-1**	**4**

Course Objectives:

- To impart basic knowledge of Nanophotonics
- To introduce the basic of Metamaterials, Surface plasma resonance, Photonic brand grip crystal.
- To enable the students to understand Nanophotonics concepts and its applications

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Basics of Nanophotonics: Photons and electrons, Quantum confinement effects, 2D, 1D, 0D structures, their growth and properties	**9**
Unit II:	**Metamaterials:** Definition of Metamaterials (MTMs) and Left-Handed (LH) MTMs, **Fundamentals of LH MTMs** Left-Handedness from Maxwell's Equations, Entropy Conditions in Dispersive Media, Boundary Conditions, Reversal of Doppler Effect, Reversal of Vavilov-˘Cerenkov Radiation, Reversal of Snell's Law: Negative Refraction, Focusing by a "Flat LH Lens"	**9**

Unit III	**Metamaterial in Optics:** Optical Properties of Metal-Dielectric Composites, Optical Magnetism, Negative-refractive Index, Perfect lens and Cloaking objects.	**9**
Unit IV	**Surface Plasmon Resonance:** Evanescent waves, Surface Plasmon dispersion equations, resonance, excitation of surface plasmons, surface Plasmon properties, SPR spectroscopy,	**9**
Unit V	**Photonic band gap crystals:** Photonics Band-Gap: Introduction to Photonics crystal, Photonic Band Structures, One dimensional, Photonic crystal: Origin of Photonics Band Gap, Size of the band gap, Evanescent Modes in Photonics Band gaps, Two-dimensional Photonic crystal: Two-dimensional Bloch States, Square Lattices (Dielectric Columns and Veins), Applications	**12**
Unit VI	Localizations of light in disordered media	**2**

Course Outcomes

CO-1:	Familiarization to the concept of Metamaterials
CO-2:	Illustration of Optical Properties in Metamaterials
CO-3:	Examine Surface Plasmon Resonance
CO-4:	Analyze Photonic Bandgap Crystals in different dimensions
CO-5:	Understanding the Importance of Silicon Photonics and Its Applications

Text Books

1. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, Christophe Caloz, Tatsuo Itoh, John Wiley and Sons, 2006
2. Optical Metamaterials, Fundamentals and Applications, Wenshan Cai Vladimir Shalaev, Springer, 2010.
3. John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, and Robert D. Meade, Photonic Crystal: Modelling Light Flow of Light, Princeton University Press, 2008.
4. Graham T. Reed and Andrew P. Knights, Silicon Photonics: An Introduction, John Wiley and Sons Ltd, 2004

Reference Books

1. Metamaterials: Physics and Engineering Explorations, Nader Engheta Richard W. Ziolkowski, Wiley and Sons,2006
2. Negative-Refraction Metamaterials Fundamental Principles and Applications, G. I. Eleftheriades K. G. Balmain, Wiley and Sons,2005
3. Gerry, Christopher C., and Peter L. Knight. Introductory quantum optics. Cambridge university press, 2023.

Course Code	Course Name	L-T-P	Credits
AP 645	**Non-linear and Quantum Optics**	**3-0-1**	**4**

Course Objectives:

- To impart basic knowledge of Nonlinear optics
- To introduce the concepts of 2nd and 3rd Order nonlinear optics and Ultrafast Optics.
- To enable the students to understand working principle of NLO & Its applications

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**Nonlinear optics basics**: Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients	**9**
Unit II:	**Second order nonlinear effects**: Second harmonic generation, Phase matching condition, Various phase matching techniques, Characterization of second order nonlinear optical materials, periodically poled materials and their applications in nonlinear optical devices. Sum and difference frequency generation, Optical parametric amplification (OPA) and oscillation (OPO), Analysis of OPA and OPO; practical device configurations and applications.	**9**
Unit III	**Third order and Higher order effects**: Third harmonic generation, Four wave mixing and Self-phase-modulation Optical Kerr effect, Self-focusing, Optical Solitons; Optical phase conjugation and Optical bistability. Stimulated Raman Scattering and Stimulated Brilluoin Scattering.	**9**
Unit IV	**Ultrafast Optics**: Introduction to ultrashort pulses, Ultrashort pulse generation through mode-locking, Nonlinear Schrödinger equation, Supercontinuum generation.	**6**
Unit V	**Quantum Optics**: Review of Quantum Mechanics basics, Quantization of electromagnetic fields, Number states, Coherent states and squeezed states of light and their properties, Beam splitters and interferometers, spontaneous parametric down conversion, concept of quantum entanglement, application of optical parametric processes to generate squeezed states of light and entangled states, applications of quantum optics.	**12**

Course Outcomes

CO-1:	Interpret the concepts of nonlinear process
CO-2:	Analyse the optical response of NLO devices
CO-3:	Examine the working principal of different NLO devices
CO-4:	Illustrate the application of NLO for ultrashort pulse generation
CO-5:	Understand the quantum optics

Text Books

1. A. Yariv and P. Yeh, Optical waves in crystals: propagation and control of laser radiation, Wiley, New York, 2002.
2. Peter E. Powers, Fundamentals of Nonlinear Optics, CRC Press, 2011.
3. A. Yariv, Quantum Electronics, John Wiley, 1989.
4. R. W. Boyd, Nonlinear Optics, Academic Press, 2008.

Reference Books

1. H.M. Moya-Cessa and F. Soto-Eguibar, Introduction to Quantum Optics (Rinton Press 2011).
2. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, 2nd ed..John Wiley, 2007.

3.	A. M. Weiner, Ultrafast Optics, Wiley Books, 2008
4.	N. Bloembergen, Nonlinear Optics, 4th Edition, (Harvard 1996)

Course Code	Course Name	L-T-P	Credits
AP 646	**Integrated Optics and Silicon Photonics**	**3-0-1**	**4**

Course Objectives:

- To impart basic knowledge of Optical waveguides and Photonics devices
- To introduce the Optical waveguide, SOI Photonics, Photonic devices.
- To enable the students to understand working principal silicon photonic devices

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Optical waveguides: Introduction to optical waveguides Differences between optical and microwave waveguides, Planar and channel waveguides, General characteristics of guided waves, Formation of optical waveguides on LiNb03, GaAs, InP, Si substrates. Electromagnetic analysis of modes in optical waveguides; The asymmetric planar waveguide, TE and TM modes in planar waveguides. Rectangular and channel waveguides; modal solutions using the effective index and perturbation methods.	12
Unit II:	**Guided-wave interactions**: Coupled mode analysis of coupled waveguide structures., Examples of coupled mode analysis - the grating reflection filter, and the directional coupler.	**6**
Unit III	Planar and Channel waveguide devices: Excitation and detection of planar guided waves, Diffraction, focusing, and collimation in planar waveguides, Diffraction devices, The Star coupler, Passive waveguide components; The power divider, Wavelength filters/multiplexers, Waveguide reflectors, Resonators, The optical time delay line. Segmented waveguides; electro-optic and acousto-optic waveguide devices. Directional couplers, optical switch; phase and amplitude modulators, Y-junction, power splitters, Arrayed waveguide devices. Tapered couplers, nonlinear effects in integrated optical waveguides.	12
Unit IV	**Silicon-on-Insulator (SOI) Photonics:** Introduction, Silicon-on-Insulator waveguides, Effective Index Method of Analysis, Large Single-mode Rib Waveguides, Refractive Index and Loss Coefficient in Optical Waveguides, coupling to the Optical Circuit; Grating Couplers, Butt Coupling and End-fire Coupling. Optical Modulation Mechanisms in Silicon, fabrication of Silicon Waveguide Devices.	**9**
Unit V	**Photonic Devices:** Optical Phase Modulators and Variable Optical Attenuators, Mach Zehnder Interferometer, Waveguide Bend, Waveguide-to-Waveguide Coupler, Arrayed Waveguide Grating (AWG), Waveguide Couplers for Small-dimension Waveguides, Advantage and Disadvantage of Silicon Photonics. Silicon **Light-emitting Devices:** Erbium Doping, Low-dimensional Structures, Dislocation-engineered Emitters	**9**

Course Outcomes	
CO-1:	Familiarization to the concept of Optical Waveguides
CO-2:	Analysis of Guided Wave Interaction
CO-3:	Understanding of Planner and Channel Waveguide Devices
CO-4:	Illustrate the Silicon-on-Insulator (SOI) Photonic devices
CO-5:	Advanced demonstration of Silicon Photonic Devices

Text Books

1. William S. C. Chang, Fundamentals of Guided-wave optoelectronics devices, Cambridge University Press,2009
2. G. T. Reed and A. P. Knights, Silicon Photonics an Introduction, John Wiley & Sons, 2004
3. T. Tamir, Ed. Integrated Optics, Springer, 2nd Ed., 1983.
4. R. Hunsperger, Integrated Optics: Theory and Technology" 6th Ed., Springer - 2009.

Reference Books

1. H. Nishihara, M. Haruna, and T. Suhara “Optical Integrated Circuits", McGraw-Hill, 1988.
2. K Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2005.
   Ghatak., and K. *Thyagarajan, Optical* Electronics, Cambridge, 1989

AP 701 Opto-Electronics Laboratory – I

Pre-requisite: Laser safety tutorials/video demonstration of Laser safety followed by written test

1. Michelson Interferometer: Setting up Michelson interferometer using a highly monochromatic laser source, evaluation of laser wavelength by fringe counting.
2. Beam Width, Divergence and M^2 measurement of He-Ne/Diode Laser with and without collimation lens.
3. Determination of the Electrical and Optical Characteristics of LED and Laser diode.
4. Designing of Optical Window, Concave and Convex Lens
5. Detection of polarization states using polarization components like polarizers, waveplates etc.
6. Analysis of various light source spectra using OSA.
7. Determination of the refractive index profile of a multimode and single mode fiber by the transmitted near field scanning technique and measurement of NA.
8. Macro and Micro bending loss in optical fibers and its application
9. Measurement of Photodiode characteristics
10. Study of Fraunhofer diffraction pattern of a rectangular and circular aperture.
11. Fiber optic link design
12. Measurement of attenuation and dispersion in optical fibers for different wavelengths
13. Fiber to Fiber splicing and splicing loss measurement.
14. Setting up of Mach-Zender interferometer
15. Measurement of Photoluminescence of an active materials using PL measurement setup.
16. Design of driver circuit for LED and Laser diode
17. Characterization of Erbium Doped Fiber Amplifier
18. Pulse width measurement of different laser using auto-correlator.
19. Holography
20. One Mini project

Note: Every student should perform a minimum of 15 experiments from the above list.

AP 702 Opto-Electronics Laboratory – II

1. Characterization of Fiber Bragg grating
2. Phase Sensitive detection technique using lock-in amplifier.
3. Power budget analysis using Optical Time Domain Reflectometer (OTDR)
4. Study of Time Division Multiplexing of digital signals
5. Study of a Wavelength Division Multiplexing(WDM) in optical fiber link
6. Study of Add/drop multiplexer
7. Study of Bit error rate and Eye pattern analysis
8. Setting up a Free space Laser Communication experiment link
9. Study of Electro-optic effect (Pockel and Kerr)
10. Measurement of third order nonlinear optical coefficient using Z-scan
11. Study of Faraday effect
12. Design of a fiber optic sensor
13. Line coding and decoding, voice coding
14. Measurement of insertion loss of an isolator, coupler and multiplexer
15. Beat length measurement in birefringent fibers.
16. Laser Raman Spectroscopy Experiments
17. M^2 measurement of different lasers
18. Measure the effect of the relative motion by using SAGNAC Interferometer

~~19.~~ Mini project

Note: Every student should perform a minimum of 15 experiments from the above list.

School Of Quantum Technolgy

SCHOOL OF QUANTUM TECHNOLOGY

M.Tech. in Quantum Computing

(Spl: Quantum Communication and Sensing)

About: Quantum technology is an emerging field of physics and engineering, which relies on the principles of quantum physics. It is about creating practical applications—such as quantum computing, quantum sensors, quantum cryptography, quantum simulation, quantum metrology and quantum imaging—based on properties of quantum mechanics, especially quantum entanglement, quantum superposition and quantum tunneling. The idea of starting a quantum technology program is keeping in mind the need for high-quality human resources for India. It will be one of the world's leading academic organizations engaged in quantum technologies.

Eligibility: The candidate should possess Master/Integrated degree or equivalent in Physics, Applied Physics, Electronic Science, Photonics

(OR)

B.E. / B.Tech / BSc. (Eng.) or equivalent in any branch

Organization: The M. Tech. Program is of four-semester duration. In each of the first two semesters, there are five courses and practical. There will be three continuous evaluation examinations and a final semester examination for every course. 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 Name	Credits			Total Credits
			L	P (in Hr)	T	
1	**QT 601**	Introduction to optics and photonics	4	0	0	4
2	**QT 602**	Introduction to Quantum Mechanics	4	0	0	4
3	**QT 603**	Introduction to Quantum Computing	4	0	0	4
4	**QT 604**	Quantum information theory	4	0	0	4
5	**QT 605**	Digital System Design and DSP using FPGA. Control systems, and Lock-in amplifiers. FPGA implementation for quantum computation systems, QKD & post processing	3	2	0	4
6	**QT 610**	Quantum Technology Laboratory-1	0	8	0	4
7	**PGC 601**	Research Methodology and IPR	2	0	0	2
		TOTAL	**21**	**10**	**0**	**26**

Semester II

Sl No	Course Code	Course Name	Credits			Total Credits
			L	P (in Hr)	T	
1	**QT 606**	Advanced Quantum communications	4	0	0	4
2	**QT 607**	Quantum Metrology and Sensing	4	0	0	4
3	**QT 608**	Quantum Computing II	4	0	0	4
4	**QT 611**	Quantum Technology Laboratory-2	0	8	0	4
5		Elective-I	4	0	0	4
6		Elective – II	4	0	0	4
7	**PGC 602**	Communication Skills & Personality Development	2	0	0	2
		TOTAL	**22**	**8**	**0**	**26**

List of Electives

Sl No	Course Code	Course
Elective I & II		
1	**QT 621**	Classical and Quantum Cryptography
2	**QT 622**	Nonlinear and Quantum Optics
3	**AM 623**	Machine Learning

Semester III

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1	**QT 651**	M.Tech Dissertation Phase – I	28 **		14
		Total	**28**		**14**

Semester IV

Sl. No.	Course Code	Course Name	Credits		Total Credits (*)
			L	T / P	
1	**QT 652**	M.Tech Dissertation Phase - II	28 **		14
		Total	**28**		**14**

***** One credit in Theory/Tutorial means one contact hour and one credit practice/Project Thesis means two contact hours in a week.

** Contact Hours/ week

Course Code	Course Name	L – T – P	Credits
QT601	**Introduction to optics and photonics**	**4 -0 -0**	**4**

Unit I

Ray optics and Maxwell's equations: Maxwell's equations and solution to Maxwell's equation. Paraxial waves, ray optics and ABCD matrices. Propagation of EM waves in free-space and material media. Helmholtz Equation, electric constant and refractive index. Vector and Scalar Potentials and Gauge invariance. Polarisers, Quarter, Half, and Full waveplates, Beam splitters: polarizing and non-polarizing,
wavelength filters, dichroic mirrors, Lenses

Unit II

Wave optics: Basic postulates of wave optics, Monochromatic waves, plane waves, spherical waves, paraxial waves. Helmholtz equation. Interference of waves. The
polarization of light, Stokes vector, Jones Calculus.

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, Generation on nanosecond and femtosecond pulses, Group velocity and Pulse
Dispersion

Unit VI

Imaging resolution: Limits on resolvability (abbe diffraction limits and beat the
limits of classical diffraction, classical techniques, NSOM, EIT, super-resolution, entangled photons)

Unit VII

Wave guides and Optical Fibers : Light Propagation in Optical Fibers, Optical fiber Modes and Configurations, Mode Theory for Circular waveguides, Single Mode, Multi-mode and Polarization Maintaining Fibres. Fiber Attenuation, Absorption losses, Scattering losses, Radiation losses, Bending losses, Dispersion in fibers, Effect
of dispersion in communication link.

Course Outcomes

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

CO-1 Understanding the fundamentals of ray optics, wave optics, and Gaussian optics.

CO-2 Mathematical description of light propagation through various optical mediums.

CO-3 Basics of laser technology and their propagation through waveguides and fibers.

CO-4 Introduction to waveguides and imaging.

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).

Course Code	Course Name	L – T – P	Credits
QT602	**Introduction to Quantum Mechanics**	4 -0 -0	4

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.

Course Outcomes

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

CO-1 The transition from classical mechanics to quantum mechanics.

CO-2 Foundations of linear algebra and complex vector spaces for quantum mechanics.

CO-3 Fundamentals of quantum mechanics principles.

CO-4 Understanding of quantum harmonic oscillator and angular momentum.

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 Code	Course Name	L – T – P	Credits
QT603	**Introduction to Quantum Computing**	**4 -0 -0**	**4**

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, 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.

Course Outcomes

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

CO-1 Introduction to single-partite and multipartite quantum states.
CO-2 Basics of quantum gates to multiqubit systems.
CO-3 Requirements and Physical realization of quantum computers
CO-4 Understanding of quantum algorithms and quantum error correction codes.

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 Code	Course Name	L – T – P	Credits
QT604	**Quantum information theory**	**4 -0 -0**	**4**

Unit I

The Quantum bit: The two-state system as the unit of information- The Qbit and ebit. Pure and mixed states. Bloch sphere and Poincare sphere representation of qubits.

Unit II

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 III

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 IV

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 V

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.

Course Outcomes

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

CO-1 Introduction to classical information theory and the concept of entropy for classical random variables.

CO-2 Understanding the von Neumann entropy and the comparison between classical and quantum information theory.

CO-3 Mathematical description of separable and entangled quantum systems.

CO-4 The conception of a qualitative and quantitative measure of entanglement.

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.

Course Code	Course Name	L – T – P	Credits
QT605	**Digital System Design and DSP using FPGA. Control systems, and Lock-in amplifiers. FPGA implementation for quantum computation systems, QKD & post-processing**	3 -2	4

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 analyser, advanced features of modern FPGAs (Kintex-7, Virtex-7, Zynq-7000, Artix-7, Kintex UltraScale, Kintex UltraScale+,Virtex UltraScale, Virtex UltraScale+, Zynq UltraScale+ 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 MicroBlaze 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
After completing this course, the students will be able to: **CO-1** Introduction to basics of FPGA systems **CO-2** Linking FPGA with various graphical programming **CO-3** Various algorithms and implementations on FPGA **CO-4** Future application of FPGA systems
References
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.
Name of experiments (QT 605) **1. The Basic Design Flow of DSP Implementation in FPGA.** 1.To understand use of Xilinx System Generator. 2.To understand Xilinx Synthesis Technology or XST. 3.Familiarization of Simulink, Signal Processing Toolbox, Signal Processing Block-set. **2. Implementation of Dual Port RAMS, Addressable Shift Register, FIFO And ROM in FPGA**. 1.Familiarization with Memory Blocks implementation in FPGA. 2.To Understand FGPGA Hardware. 3.Familiarization of XUP board (Vertex-5). **3. Implementation of M Code Adder in FPGA** 1.This exercise provides an introduction to the integration of M Code into a System Generator System. 2.To understand the functionality of a basic 2-input adder is interpreted from the M-code. **4. Generation of Simulink System Period** 1.To understand Simulink system periods, and confirm the meaning of this parameter from the simulation results.

Course Code	Course Name	L – T – P	Credits
QT610	**Quantum Technology Laboratory-1**	**0-8**	**4**
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 M2 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. Demonstration of BB84 protocol 16. Quantum random number generation	
Course Outcomes	
After completing this course, the students will be able to: **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.	

Course Code	**Course Name**	**L – T – P**	**Credits**
QT 606	**Advanced Quantum communications**	**4 -0 -0**	**4**
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** Shennon 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			
Course Outcomes			
After completing this course, the students will be able to: **CO-1** Advanced classical cryptography technics and their applications. **CO-2** Limitations of classical cryptography and the necessity of QKD protocols. **CO-3** Introduction to various QKD protocols and their realization **CO-4** Present trends in QKD			

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

Course Code	Course Name	L – T – P	Credits
QT 607	**Quantum Metrology and Sensing**	**4 -0 -0**	**4**

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 interferometery, Joshpson 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

Course Outcomes

After completing this course, the students will be able to:
CO-1 Introduction to atomic, molecular and optical physics
CO-2 Quantum principles and their applications to information and imaging.
CO-3 Quantum sensing using cold atoms
CO-4 Introduction to frequency standards

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 Code	Course Name	L – T – P	Credits
QT608	**Quantum Computing II**	**4 -0 -0**	**4**

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.

Course Outcomes

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

CO-1 Introduction to classical deterministic and probabilistic quantum systems; and the leap from classical mechanics to quantum mechanics.

CO-2 Conception of physical realization of qubits.

CO-3 Implementation of various quantum algorithms using QISKIT - IBM Quantum experience.

References

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> !Who's Excited?. arXiv:1711.02086.2017.
4. Christopher M. Dawson, Michael A. Nielson. The Solovay–Kitaev Algorithm. Quantum Information and Computation. 2005.
5. Klaus Mølmer, Anders Sørensen. Multi-particle entanglement of hot trapped ions. Physical Review Letters 82. 1999.
6. Vivek V. Shende, Igor L. Markov. On the CNOT-cost of TOFFOLI gates. Quan- tum Information and Computation. 2009.
7. 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 Code	**Course Name**	**L – T – P**	**Credits**
QT 611	**Quantum Technology Laboratory-2**	**0-8**	**4**

01. Demonstration of Quantum Zeno effect
02. Tomographic single photon state reconstruction
03. Demonstration of wave nature of photons
04. Setting up Quantum eraser system
05. Test of wave particle dualism
06. Visible light interference
07. Measurement of wavelength of single photons
08. Coherence length measurement of single photons
09. Interaction-free measurement
10. Test of Bell's inequality (CHSH) violation
11. Non-classical polarization correlations
12. Tomographic state reconstruction
13. Demonstration of QKD (BBM protocol)
14. Ekert protocol – test
15. Hong-Ou-Mandel two-photon interferometers
16. 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.

Course Code	Course Name	L – T – P	Credits
QT 621	**Classical and Quantum Cryptography (Elective)**	**4 -0 -0**	**4**

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 Alzebra, 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.

Course Outcomes

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

CO-1 Understanding the Mathematical description of cryptography
CO-2 Introduction to classical cryptography
CO-3 Modeling of public key cryptosystems
CO-4 Understanding the fundamentals of Post-quantum cryptography

References

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 Code	Course Name	L – T – P	Credits
QT 622	**Nonlinear and Quantum Optics (Elective)**	**4 -0 -0**	**4**

Unit I

Nonlinear optics: Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients. Second harmonic generation

Unit II

Nonlinear Optics: 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

Nonlinear Optics: Third harmonic generation, four wave mixing and Self phase- modulation Optical Kerr effect, Self-focusing, Optical bistability, Stimulated Raman Scattering and Stimulated Brilluoin Scattering, Introduction to ultrashort pulses,
Ultrashort pulse generation through mode-locking, Supercontinuum generation

Unit IV
Quantum Optics: Field quantization, Correlation functions, photon statistics, shot noise of the photodetectors, Poissonian and sub-Poissonain light, Photon bunchingand antibunching, HBT experiment

Unit V
Quantum Optics: single photon sources, Coherent states and squeezed states, Phasor diagram, generation and detection of squeezed light, Quantum noise, Phase space representation and Wigner function.

Course Outcomes

After completing this course, the students will be able to:
CO-1 Introduction to nonlinear optics and their applications
CO-2 Understanding of various second order nonlinear optical processes and critical and quasi-phase matching techniques
CO-3 Conception of various third and higher order nonlinear effects
CO-4 Introduction to field quantization and quantum optics
CO-5 Introduction to various quantum states of light

References

1. R. W. Boyd, Nonlinear Optics, Academic Press, 2008
2. Peter E. Powers, Fundamentals of Nonlinear Optics, CRC Press, 2011.
3. Mark Fox, Quantum Optics: An Introduction, Oxford master series in physics, 2007
4. A guide to experiments in Quantum Optics, Hans-A Bachor, T. C. Ralph, 3rd edition, Wiley, 2019

Course Code	Course Name	L – T – P	Credits
AM 623	**Machine Learning (Elective)**	**4 -0 -0**	**4**

Unit I
Introduction - Well-posed learning problems, Designing a learning system, Perspectives and issues in machine learning Concept learning and the general to specific ordering – Introduction, A concept learning task, Concept learning as search, Find-S: finding a maximally specific hypothesis, Version spaces and the candidate elimination algorithm, Remarks on version spaces and candidate elimination, Inductive bias

Unit II
Decision Tree learning – Introduction, Decision tree representation, Appropriate problems for decision tree learning, The basic decision tree learning algorithm, Hypothesis space search in decision tree learning, Inductive bias in decision tree learning, Issues in decision tree learning 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 III
Bayesian learning – Introduction, Bayes theorem, Bayes theorem and concept learning, Maximum likelihood and least squared error hypotheses, Maximum likelihood hypotheses for predicting probabilities, Minimum description length principle, Bayes optimal classifier, Gibs algorithm, Naïve Bayes classifier, An example learning to classify text, Bayesian belief networks The EM algorithm, Computational learning theory – Introduction, Probability learning an

approximately correct hypothesis, Sample complexity for Finite Hypothesis Space, Sample Complexity for infinite Hypothesis Spaces, the mistake bound model of learning - Instance-Based Learning-Introduction, k -Nearest Neighbour Learning, Locally Weighted Regression, Radial Basis Functions, Case-Based Reasoning, Remarks on Lazy and Eager Learning

Unit IV

Genetic Algorithms – Motivation, Genetic Algorithms, an illustrative Example, Hypothesis Space Search, Genetic Programming, Models of Evolution and Learning, Parallelizing Genetic Algorithms, Learning Sets of Rules – Introduction, Sequential Covering Algorithms, Learning, Rule Sets: Summary, Learning First Order Rules, Learning Sets of First Order Rules: FOIL, Induction as Inverted Deduction, Inverting Resolution

Unit V

Analytical Learning - Introduction, Learning with Perfect Domain Theories: Prolog- EBG Remarks on Explanation-Based Learning, Explanation-Based Learning of Search Control Knowledge, Combining Inductive and Analytical Learning – Motivation, Inductive-Analytical Approaches to Learning, Using Prior Knowledge to Initialize the Hypothesis, Using Prior Knowledge to Alter the Search Objective, Using Prior Knowledge to Augment Search Operators,

Unit VI

Reinforcement Learning – Introduction, the Learning Task, Q Learning, Non- Deterministic, Rewards and Actions, Temporal Difference Learning, Generalizing from Examples, Relationship to Dynamic Programming.

Course Outcomes

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

CO-1 Introduction to learning systems
CO-2 Computational learning theory and its applications
CO-3 Brief overview of various optimization algorithms
CO-4 Introduction to Analytical learning and reinforcement learning

References

1. Machine Learning – Tom M. Mitchell, - MGH
2. Machine Learning: An Algorithmic Perspective, Stephen Marsland, Taylor & Francis (CRC)
3. Machine Learning Methods in the Environmental Sciences, Neural Networks, William W Hsieh, Cambridge Univ Press.
4. Richard o. Duda, Peter E. Hart and David G. Stork, pattern classification, John Wiley & Sons Inc., 2001.
5. Chris Bishop, Neural Networks for Pattern Recognition, Oxford University Press, 1995

Department Technology Management

DEPARTMENT OF TECHNOLOGY MANAGEMENT

M.Tech. in Technology Management

SEMESTER I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	TM 601	Introduction to Technology Management	3	1	4
2	TM 602	R&D and Innovation Management	3	1	4
3	TM 603	Project Management	3	1	4
4	TM 604	Strategic Management for Technology	3	1	4
5	TM 605	Applied Statistics for Management-I	3	1	4
6	TM 615	Human Resource Management for Technology intensive organizations	3	1	4
7	PGC 601	Research Methodology and IPR	2	0	2
		Total	**20**	**6**	**26**

SEMESTER II

Sl. No.	Course Code	Course	Contact hours/week		Credits
			L	T/P	
1	TM 610	Leadership & Organizational Behaviour	3	1	4
2	TM 612	Quality Management	3	1	4
3	TM 617	Logistics and Supply Chain Management	3	1	4
4	TM 622	Applied Statistics for Management-II	3	1	4
5		Elective – I	3	1	4
6		Elective – II	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	**20**	**6**	**26**

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	TM 651	M.Tech. Dissertation Phase I	28		14
		Total	**28**		**14**

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	TM 652	M.Tech. Dissertation Phase II	28		14
		Total	**28**		**14**

List of Electives:

Sl. No.	Course Code	Course Name
Elective I, II		
ELECTIVES FROM DEPARTMENT (Semester 2)		
1	TM 607	Management of Manufacturing and Integration
2	TM 608	Knowledge Management
3	TM 609	Systems Engineering for Managers
4	TM 611	Software Projects Management
5	TM 613	Value Engineering
6	TM 614	Design Management
7	TM 616	Introduction to Enablers of Nation Building
8	TM 618	Operations Management
9	TM 619	Advanced Project Management Techniques
10	TM 620	Accounting and Finance for Technologists
11	TM 621	Artificial Intelligence (AI) in Management
ELECTIVES FROM OTHER DEPARTMENT		
12		Open Electives from other departments
* 1 Credit in Theory/Tutorial means 1 contact hour and 1 credit in practice/Project Thesis means 2 contact hours in a week		

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 solution/decision.

PO3: To give managerial as well as academic interpretations based on management by facts and put it into formal documentations. To achieve excellence in management decisions.

Program Specific Outcomes (PSOs)

PSO1: To learn the basics and advances in Technology management perspective. To emphasize the need for adequate knowledge and competence in Technology. To overcome the time & cost overruns of various defence related projects.

PSO2: Proper utilization of human resources and their intellectual abilities for betterment in projects, R&D and strategy formation decisions.

PSO3: To learn various management cases through problem solving approach inclined to corporate decisions.

Course Code	Course Name	L – T – P	Credits
TM601	**INTRODUCTION TO TECHNOLOGY MANAGEMENT**	**3-1-0**	**4**

Course Objectives:

- The objective of this course is to provide students with a comprehensive understanding of the strategic role and evolution of technology in modern organizations.
- Students will learn to manage technology resources effectively, integrate technological innovations, and leverage technology for competitive advantage.
- Key topics include technology life cycle, technology strategy, innovation management, technology forecasting, product development, and the impact of emerging technologies on business processes.
- By the end of the course, students will be able 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:** Understand the issue around Technology management, Technology Cycle and wealth creation through technological development. **CO2:** Identify the technology decisions for push-pull, assessments, strategy. **CO3:** Understanding 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
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**	**3-1-0**	**4**

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

Foundations of R&D Management - 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** *Technology Innovation Management* - 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** *Human Resource & Intellectual Property Management*- 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:** Gain insight into R&D's definition and significance in the tech sector; distinguish between basic research, applied research, and development for strategic planning. 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. Utilize technology forecasting methods and recognize the role of incubators in fostering innovation for sustainable technological advancement. **CO3:** Align human resource strategies with R&D objectives, fostering a culture of creativity and collaboration. Manage team dynamics proficiently, building and sustaining effective R&D teams. Design reward systems, handle performance appraisal processes, 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. Hawthrone 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 CollegePress 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

Course Code	Course Name	L – T – P	Credits
TM603	**PROJECT MANAGEMENT**	**3-1-0**	**4**

Course Objectives:

- The objective of this course is to equip students with the essential knowledge and skills required to successfully initiate, plan, execute, control, and close projects.
- Students will learn about project management methodologies, tools, and best practices. Key topics include project scope, time, cost, quality, risk management, stakeholder engagement, and team dynamics.
- By the end of the course, students will be able to apply project management principles to deliver projects on time, within budget, and to the specified quality standards, thereby contributing to the strategic objectives of their organizations.

Course Contents

Unit I

Project Systems Management: a life cycle approach, stage-gate model, project characteristics; project life cycle phases: conception, definition, planning and organising, implementation and project clean up, Management of projects. Development of Project Charter, Organization Strategy and Project Selection. Project feasibility analysis, The project manager: role and responsibilities, Tools and techniques for project management, Environmental impact analysis of a project.

Unit II

Project Scope Management, Stakeholder Management, Project Managing Risks, Network techniques for project management-PERT and CPM Accounting for risk, uncertainty and fuzziness. Time cost tradeoffs and crashing procedures. Multi project planning and scheduling with limited resources

Unit III

Projects financing, performance budgeting and control. Project materials management. Pricing, estimating, and Contract Administration and Management, Building and Bid evaluation and analysis. Project implementation and monitoring, Project management information and control systems. Project systems management performance indices. Project Closure and handover, Software Packages application for Project Systems Management. Case studies.

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.,Mereddith 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**	**3-1-0**	**4**

Course Objectives:

- The business world today is considerably different and more complex than it was in the previous years. Both the challenges and opportunities facing organizations of all sizes today are greater than ever.
- Organizations are required to continuously find better ways to compete in the rapidly changing global business environment. Survival and competition have become imperative for organizations in the current global scenario.
- In this context, the course develops the strategic thinking and decision making abilities of students, especially in relation to understanding the employability of various strategies in different situations.

Course Contents

Unit I

Strategic Management Process; Challenge of Globalization; Strategic Planning in India; Corporate Governance; Board of Directors; Role and functions of Top Management, Environmental scanning: Industry Analysis, Internal Scanning: Organizational Analysis

Unit II

Strategy Formulation: Situation Analysis and Business Strategy, Corporate Strategy, Functional Strategy, Strategy Implementation and Control, Strategic Alternatives; Diversification, Mergers and Acquisitions.

Unit III Case Studies-Demonetization, Strategic initiatives of Govt. of India, FDI in defence, start-ups, "Make in India" for document of cutting edge technology coming from abroad-offset policies, Freedom to operate, strategic aspects of Technology Management
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 dynamic global business environment in terms of rapidly changing market trends 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	**APPLIED STATISTICS FOR MANAGEMENT-I**	**3-1-0**	**4**

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. Utilize measures of central tendency and variability to analyze data, construct frequency distributions, and understand basic probability concepts crucial for managerial insights.

CO2: Apply inferential statistics principles, including sampling theory and the Central Limit Theorem, for accurate decision-making. Construct confidence intervals and conduct hypothesis testing, ensuring reliable conclusions in the face of Type I and Type II errors, employing Z-tests and t-tests proficiently.

CO3: Employ descriptive and inferential statistics to address technology management challenges effectively. 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	**HUMAN RESOURCE MANAGEMENT FOR TECHNOLOGY INTENSIVE ORGANISATIONS**	**3-1-0**	**4**

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 Anlaytics issues and metrices, 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, Develop an ability to undertake qualitative and quantitative research, Apply knowledge about qualitative and quantitative research to an independently constructed piece of work

CO2: Respond positively to problems in unfamiliar contexts, Identify and apply new ideas, methods and ways of thinking, Demonstrate competence in communicating and exchanging ideas in a group context

CO3: Be able to advance well-reasoned and factually supported arguments in both written work and oral presentations, Work effectively with colleagues with diverse skills, experience levels and way of thinking

CO4: Leverage different analytics approaches—predictive, prescriptive and inferential across business domains and 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 Resourse 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**	**3-1-0**	**4**

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; Motivational theory, Leadership style, Communication skills development, Development of Personality, transactional analysis, ego states, Johari window

Unit II

Organisation Culture: functions of culture, ethical dimensions; Organisation Management : Management skills, Management types, Management by Objectives, Change Management, Organisation Diversity: Diversity and Inclusivity as a Value Based Imperative

Unit III

Interpersonal relations: Stages in Interpersonal Relationships, Factors affecting Interpersonal Relationship, Team Building: Difference between Group and Team**,** Team Development - Meaning, Stages and Forming an Effective Team, Effective Team Management Skills, Values and Ethics, Conflict Management : Understanding conflict & how to prevent it, Conflict Management Skills, Importance, Conflict Management at Workplace, Negotiation: Types, Models of Negotiation, Workplace Politics, Case study

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, Discuss the impact that diversity of race, gender, ability, religion, and age has on the workplace

CO2: Describe the methods of encouraging ethical behavior and the laws encouraging good corporate practices, Discuss the impact organizational culture has on individuals and the workplace

CO3: Strategies to improve motivation in the workplace, importance of managing stress and emotions in the workplace, appropriate methods and styles of communication in the workplace

CO4: Strategies for managing conflict and negotiation in the workplace, process and techniques of individual and group decision-making, Recognize good and poor leadership and the varieties of leadership, impact organizational change has on individuals and the workplace

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	**QUALITY MANAGEMENT**	**3-1-0**	**4**

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 as well as 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.

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	**APPLIED STATISTICS FOR MANAGEMENT -II**	**3-1-0**	**4**

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: Master regression analysis techniques to discern variable relationships and interpret coefficients for informed managerial decisions. 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. Apply non-parametric tests effectively across diverse scenarios, enhancing the reliability of managerial insights.

CO3: 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**	**3-1-0**	**4**

Course Objectives:

The objective of this course is to provide students with a comprehensive understanding of supply chain management principles and practices. Students will learn 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 and contribute to the overall competitiveness of organizations in a global market.

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, 4th edition, Prentice-Hall Inc., New Jersey, (1994

ELECTIVES FROM DEPARTMENT

Course Code	Course Name	L – T – P	Credits
TM607	**MANAGEMENT OF MANUFACTURING AND INTEGRATION**	**3-1-0**	**4**

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**	**3-1-0**	**4**

Course Objectives:

- The objective of this course is to prepare students to understand the current theories, practices, tools and techniques in knowledge management (KM) to deal with the challenges with the organization and management of knowledge.

Course Contents

Unit I

Data Information Knowledge wisdom, Knowledge cycle, Basics of Knowledge Management(KM), Learning Organizations & Open innovation, Role of KM in technology-intensive firms.

Unit II

Knowledge transfer in Organizations, Human aspects of Knowledge Management, Evaluation of Knowledge Management effectiveness: Tools & Techniques

Unit III

Knowledge Management experiences from Indian companies, Knowledge Management practices of select industries, Knowledge portals, Future & Applications of Knowledge Management, Case studies

Course Outcomes

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

CO1: Understand Apply complex theories and practice of knowledge and intellectual capital management

CO2: Understand Apply theories to a wide range of scenarios

CO3: Formulate action plans for knowledge intensive organizations

CO4: Distinguish aspects of industrial era management that may be inappropriate for knowledge intensive organizations and provide alternatives

CO5: Understand Formulate a framework for thinking about knowledge intensive organizations

CO6: Understand, describe and work with intangibles

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**	**3-1-0**	**4**

Course Objectives:

The objective of this course is to prepare students :

- Apply fundamental knowledge and skill sets required in the Industrial and Systems Engineering profession.
- Adopt a systems approach to design, develop, implement and innovate integrated systems that include people, technology, information, energy and resources taking into account global, societal, environmental and economic contexts.
- Work and communicate effectively with multi-disciplinary team members and different types of stakeholders.
- Recognize the need and continue to develop skills and knowledge to embrace changes in society and the profession.

Course Contents

Unit I

Systems engineering and the world of modern systems

Nature and Scope of Systems Engineering, Origins of Systems Engineering, The Power of Systems Engineering, Examples of Systems Requiring Systems Engineering

Unit II

Structure of complex systems:

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

The system development process

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

Systems Engineering Management

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 Explain how system engineering methodologies make for an orderly design process **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, Weigh the strengths and weaknesses of system thinking and service thinking, Outline how product-service systems can be designed to support in-service systems
CO5: Demonstrate professional skills including participation in and running meetings; effective team membership and leadership; 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 Books

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**
TM611	**SOFTWARE PROJECT MANAGEMENT**	**3-1-0**	**4**

Course Objectives:

- This course is aimed at introducing the primary important concepts of project management related to managing software development projects.
- They will also get familiar with the different activities involved in Software Project Management. Further, they will also come to know how to successfully plan and implement a software project management activity, and to complete a specific project in time with the available budget.

Course Contents

Unit I

Introduction to Software Project Management: Software projects versus other types of project, Activities Covered by software project management, Some ways of categorizing software projects, Stakeholders, Project success and failure.; *Project Evaluation and Programing Management*: Project portfolio management, Evaluation of individual projects, Cost-benefits Evaluations techniques, Risk Evaluation, Programme management, managing the Allocation of Resources within programmes, Aids to programme management; *An overview of Project Planning:* Introduction Step wise project planning; *Selection of an Appropriate Project Approach*: Build or Buy?, Choosing Methodologies and Technologies , Software processes and process Models , Choices of process Models , Structure versus speed of Delivery , The waterfall Model , The Spiral Model , Software prototyping , Other Ways of Categorizing Prototypes ,incremental Delivery , Atern/ Dynamic systems development methods , Rapid application development , Agile methods , Extreme programming (XP), Scrum , Managing Iterative processes , Selecting the most appropriate process Model.

Unit II

Software Effort Estimation: The basis for software estimating, Software effort estimation techniques , Bottom up estimating, the top-down Approach and parametric models ,Expert Judgement , estimating by analogy ,Albrecht function point analysis, COSMIC full function points , COCOMO II : A parametric productivity Model , cost estimation; .*Activity Planning*: Sequencing and Scheduling Activities, Network planning Models, Formulating a Network Model, Identifying the Critical path; *Risk Management*: Categories of risk, Risk identification , Risk assessment , Risk planning, Risk management , Evaluating risks to the schedule , Monte carlo simulation; *Resource Allocation:* The nature of Resources ,Identifying Resource Requirements, Scheduling resources , Counting the cost ,Being specific , Cost schedules

Unit III

Monitoring And Control: Creating the framework, visualizing progress, cost monitoring, earned value analysis, prioritizing monitoring, Getting the project Back to target, Software Configuration management (SCM); *Managing Contracts*: Stages in contract placement, typical terms of a contract, Contract management, Acceptance; *Working In Teams*: Becoming a team, Decision making , Organization and team strictures , Dispersed and virtual teams , Communication plans; *Software Quality*: Defining software Quality, ISO 9126, Product and process metrics, , Quality management systems, process capability models , techniques to Help Enhance software Quality , software reliability.

Course Outcomes

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

CO1: Get an overview of Software project management, its evaluation, management and approach. Learn the concept of Agile Project Management.

CO2: Calculate the software effort estimation through various methods

CO3: Determine the Project management scheduling through activities, Risk associated and resource association

CO4: Monitoring and control of overall project for assessing the project successfulness

CO5: Understanding software quality and reliability concept and its certification.

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. Pankaj Jalote:Software Project Management in Practice, Pearson 2. Bob Hughes, Mike Cotterell, Rajib Mall: SOFTWARE PROJECT MANAGEMENT (5th edition),-McGraw Hill Education. 2016 3. Taylor James:Managing Information Technology Projects: Applying Project Management Strategies To Software, Hardware, And Integration Initiatives 1st Edition, AMACOM 4. Gunther Ruhe &Claes Wohlin:Software Project Management in a Changing World, Springer 5. Hughes, Software Project Management, 5th edition, SIE Publication. 6. Royce, Software Project Management: A Unified Framework, 1e, Pearson Publication.

Course Code	Course Name	L – T – P	Credits
TM613	**VALUE ENGINEERING**	**3-1-0**	**4**

Course Objectives:

- Finding optimal solutions to balance the actual project requirements with the available resources and means, and helping to use analytical and creative thinking.
- Creating sufficient awareness of the importance of achieving ideal value for projects or services and eliminating unnecessary costs while raising quality and performance.
- Knowing how to start risk management through value engineering by laying the foundation stone to determine the real costs of projects before entering into the risks of managing changes.
- Know how to judge 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: Reference to acquire the basic concept of value engineering and value analysis.

CO2: It gives functional approach to value improvement and various techniques of the job plan

CO3: Illustrations and In depth concept of life cycle costing and its methods.

CO4: Enriching value to the system through cognition and creativity and its usefulness.

CO5: Evaluation of various value enrichment alternatives and making decision through matrix.

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 l. 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**	**3-1-0**	**4**

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.
- We identify and explore design attributes that positively influence a projects performance and the pitfalls that can derail a project.
- How 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: Developing design perceptions and its effect on competitiveness.

CO3: Learn data elicitation techniques and various analysis useful for design management.

CO4: Understanding the design thinking, value analysis and value engineering.

CO5: Various applications of computer in design management. 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**	**3-1-0**	**4**

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

Introduction and Basic Concepts of National Service Scheme (NSS): History, philosophy, aims & objectives of NSS, Emblem, flag, motto, song, badge etc., Organizational structure, roles and responsibilities of various NSS functionaries.

Unit II

Life competencies & Disaster Management: 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

Entrepreneurship Development: Definition & Meaning, Qualities of good entrepreneur, Steps/ways in opening an enterprise, Role of financial and support service Institutions.

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**	**3-1-0**	**4**

Course Objectives:

- To obtain an understanding of quality management practice in organizations and how total quality management and six-sigma 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**	**3-1-0**	**4**
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 (5^{th} 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**	**3-1-0**	**4**

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.illionois
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, Finanacial 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**	**3-1-0**	**4**

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

Beginning of an AI Journey: 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

Choosing the right AI technique: 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

Using AI successfully and responsibly: 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:** Attain foundational AI knowledge, including the 7 Principles of an AI Journey. Master data preparation techniques like the TUSCANE Approach and Data Pre-processing, and hone skills in selecting appropriate AI solutions using the FAB-4 model. **CO2:** Comprehend diverse AI techniques such as Classification, Regression, Decision trees, Ensemble learning, Clustering, Reinforcement learning, Natural Language processing, and Deep Learning (ANN, CNN). Develop expertise in selecting the most suitable AI technique for specific applications. **CO3:** Acquire the know-how to deploy AI responsibly in organizations, covering AI adoption phases, investment and valuation strategies, and risk management. Gain insights into human-AI work policy principles and effectively mitigate risks associated with AI implementation. **CO4:** 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 Brigette Tasha Hyacinth

Department of Electornics Engineering

M. Tech. in Electronics and Communication Engineering (Signal Processing and Communication)

Semester I

Sl. No	Course Code	Course Title	Contact Hours/ Week		*Credits
			L	T/P	
1.	EE 601	Microwave Engineering	3	1	4
2.	EE 602	Digital Signal Processing	3	1	4
3.	EE 603	Wireless and Mobile Communication	3	1	4
4.	EE 604	Radar System Design	3	1	4
5.	EE 624	Digital System Design using FPGA	3	1	4
6.	AM 607	Mathematics for Engineers	3	1	4
7	PGC 601	Research Methodology and IPR	2	0	2
		Total	20	6	26

Semester II

Sl. No	Course Code	Course Title	Contact Hours/ Week		*Credits
			L	T/P	
1	EE 606	Statistical Signal Processing	3	1	4
2	EE 607	Detection and Estimation Theory	3	1	4
3		Departmental Elective I	3	1	4
4		Departmental Elective II	3	1	4
5		Elective – III	3	1	4
6		Elective – IV	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	20	6	26

* 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	EE 651	M.Tech. Dissertation Phase I	28**		14
		Total	28		14

Semester IV

Sl. No	Course Code	Course Title	Contact Hours /week		*Credits
			L	T/P	
1	EE 652	M.Tech. Dissertation Phase II	28**		14
		Total	28		14

*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**

M. Tech. in Electronics and Communication Engineering (Radar and Communication)

Semester I

Sl. No	Course Code	Course Title	Contact Hours/ Week		Credits
			L	T/P	
1.	EE 601	Microwave Engineering	3	1	4
2.	EE 602	Digital Signal Processing	3	1	4
3.	EE 603	Wireless and Mobile Communication	3	1	4
4.	EE 604	Radar System Design	3	1	4
5.	EE 624	Digital System Design using FPGA	3	1	4
6.	AM 607	Mathematics for Engineers	3	1	4
7	PGC 601	Research Methodology and IPR	2	0	2
		Total	20	6	26

Semester II

Sl. No	Course Code	Course Title	Contact Hours/ Week		Credits
			L	T/P	
1	EE 610	Radar Signal Processing	3	1	4
2	EE 609	Antenna Systems	3	1	4
3		Departmental Elective I	3	1	4
4		Departmental Elective II	3	1	4
5.		Elective – III	3	1	4
6.		Elective – IV	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	20	6	26

* 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	EE 651	M.Tech. Dissertation Phase I	28**		14
		Total	28		14

Semester IV

Sl. No	Course Code	Course Title	Contact Hours /week		*Credits
			L	T/P	

1	EE 652	M.Tech. Dissertation Phase II	28**	14
		Total	28	14

*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**

M. Tech. in Electronics and Communication Engineering (Defence Electronics Systems)

Semester I

Sl. No	Course Code	Course Title	Contact Hours/ Week		Credits
			L	T/P	
1.	EE 601	Microwave Engineering	3	1	4
2.	EE 602	Digital Signal Processing	3	1	4
3.	EE 603	Wireless and Mobile Communication	3	1	4
4.	EE 604	Radar System Design	3	1	4
5.	EE 624	Digital System Design using FPGA	3	1	4
6.	AM 607	Mathematics for Engineers	3	1	4
7	PGC 601	Research Methodology and IPR	2	0	2
		Total	20	6	26

Semester II

Sl. No	Course Code	Course Title	Contact Hours/ Week		Credits
			L	T/P	
1	EE 609	Antenna Systems	3	1	4
2	EE 614	EMI/EMC Design	3	1	4
3		Departmental Elective I	3	1	4
4		Departmental Elective II	3	1	4
5.		Elective – III	3	1	4
6.		Elective – IV	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	20	6	26

*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	EE 651	M.Tech. Dissertation Phase I	28**		14

		Total	28	14

Semester IV

Sl. No	Course Code	Course Title	Contact Hours /week		*Credits
			L	T/P	
1	EE 652	M.Tech. Dissertation Phase II	28**		14
		Total	28		14

*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**

M. Tech. in Electronics and Communication Engineering (VLSI and Embedded Systems)

Semester I (@DIAT, Pune)

Sl. No	Course Code	Course Title	Contact Hours/ Week		Credits
			L	T/P	
1.	EE 602	Digital Signal Processing	3	1	4
2.	EE 621	Digital IC Design	3	1	4
3.	EE 622	RF IC Design	3	1	4
4.	EE 650	Semiconductor devices for high speed and high power applications	3	1	4
5.	EE 624	Digital System Design using FPGA	3	1	4
6.	AM 607	Mathematics for Engineers	3	1	4
7	PGC 601	Research Methodology and IPR	2	0	2
		Total	20	6	26

Semester II (@DIAT, Pune)

Sl. No	Course Code	Course Title	Contact Hours/ Week		Credits
			L	T/P	
1.	EE 638	Analog and Mixed mode VLSI Design	3	1	4
2.	EE 648	VLSI Fabrication Technology	3	1	4
3.		Departmental Elective I	3	1	4
4.		Departmental Elective II	3	1	4
5.		Elective – III	3	1	4
6.		Elective – IV	3	1	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	20	6	26

Semester III (@ NIELIT CALICUT)

Sl. No	Course Code	Course Title	Contact Hours /week		*Credits
			L	T/P	
1	EE 651	M.Tech. Dissertation Phase I	28**		14
		Total	28		14

Semester IV (@ NIELIT CALICUT)

Sl. No	Course Code	Course Title	Contact Hours /week		*Credits
			L	T/P	
1	EE 652	M.Tech. Dissertation Phase II	28**		14
		Total	28		14

*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

Semester III and Semester IV [Project work and VLSI related Courses @ NIELIT CALICUT].

List of Electives

Sl. No.	Course Code	Course Title	Contact hours/week		Credits
			L	T/P	
1	EE 605	Navigation System Concepts	3	1	4
2	EE 608	Modern Wireless Communications	3	1	1
3	EE 612	High Power Microwave Systems	3	1	4
4	EE 613	Electronic Warfare	3	1	4
5	EE 619	Software Defined Radio	3	1	4
6	EE 620	SoC and Embedded Systems	3	1	4
7	EE 623	Semiconductor Devices	3	1	4
8	EE 625	High Performance DSP using FPGA	3	1	4
9	EE 626	Compressed Sensing & Sparse Signal Processing	3	1	4
10	EE 627	Signal Theory, Linear Algebra & Transform Techniques	3	1	4
11	EE 628	Advanced Electronics Systems	3	1	4
12	EE 629	Sonar Signal Processing	3	1	4
13	EE 630	Sonar System Engineering	3	1	4
14	EE 631	Satellite Communication	3	1	4
15	EE 632	Advanced Communication Systems	3	1	4
16	EE 633	Underwater Communications	3	1	4

17	EE 634	Monolithic Microwave Integrated Circuit	3	1	4
18	EE 635	Inertial Sensors and Systems	3	1	4
19	EE 636	Navigation & Avionic Systems	3	1	4
20	EE 637	ASIC Verification using System Verilog	3	1	4
21	EE 638	Analog and Mixed mode VLSI Design	3	1	4
22	EE 639	Computer Aided Design for VLSI Circuits	3	1	4
23	EE 640	FPGA Architecture and Applications	3	1	4
24	EE 641	VLSI Signal Processing	3	1	4
25	EE 642	SoC Design and Verification	3	1	4
26	EE 643	Digital Interface Design	3	1	4
27	EE 644	MIMO Communications	3	1	4
28	EE 645	Advanced Digital Signal Processing	3	1	4
29	EE 646	Advanced Simulation Techniques	3	1	4
30	EE 647	RF Photonics	3	1	4
31	EE 648	VLSI Fabrication Technology	3	1	4
32	EE 649	Introduction to Electronics Systems	3	1	4
33	EE 650	Semiconductor devices for high speed and high-power applications	3	1	4
34	EE 653	Quantum Transport in nanoscale FETs	3	1	4

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)

PSO1: The M.Tech. Electronics & Communication Engineering aims at developing skilled knowledgeable human task force in the field of radar and signal processing, catering the needs of defense, social, and DRDO requirements.

PSO2: The M.Tech. Electronics & Communication Engineering aims at developing skilled knowledgeable human task force in the field of VLSI and Embedded systems, Defence Electronics systems, catering the needs of defense, Semiconductor industries and DRDO requirements.

Detailed Contents

Course Name: MICROWAVE ENGINEERING
Course Code: EE601

Course Outcome-

Course Outcomes	Description
CO1	Understanding of fundamentals of Maxwell's equations and Transmission line theory.
CO2	Understanding of the various Two-port Parameters Z-Matrix, Y-Matrix, ABCD-Matrix, S-Matrix
CO3	Students will understand the basics of microwave components and design: Directional Couplers, Filters, Power dividers, Amplifiers.

UNIT-I: INTRODUCTION TO EM WAVE AND TRANSMISSION LINES Introduction to microwaves, Maxwell' s equations, wave Equation, Plane wave reflection, Dielectric Interference, circuit model and field analysis, Quarter-wave transformer, lossy transmission lines, TEM, TE and TW wave solutions, types of waveguides, strip lines, relation between dB, dBm, dBw, dB.

UNIT-II: MICROWAVE NETWORK ANALYSIS: Impedance, voltage, current, Matrices, scattering, transmission (ABCD) matrix, signal flow graph, Discontinuities and Model analysis, Excitation of waveguides, Lumped elements, stub tuning, Binomial and Chebyshev multi-section, tapered lines, Bode-Fano criterion.

UNIT-III: MICROWAVE RESONATORS, DIVIDERS AND COUPLERS: Serial and parallel resonant circuit, line resonators, Cavity resonators, Excitation of resonators, cavity perturbations, properties of dividers and couplers, Wilkinson power dividers, directional couplers, Quadrature (90°) Hybrid, Coupled line directional couplers, large couplers, other couplers.

UNIT-IV: MICROWAVE FILTERS: Periodic structures filter design by Image Parameter Method, Insertion loss method, filter transformation, filter implementation, stepped-Impedance low-pass filters, coupled line filters, filters using coupled resonators.

UNIT-V: MICROWAVE DEVICE AND AMPLIFIES DESIGN: Diode circuits, BJT, FET, Microwave integrated circuits, Microwave tubes, RF oscillators, Microwave oscillators, Phase noise, frequency multiplier, mixers, Two-port power gain, single stage- broadband transistor amplifier design, power amplifiers.

UNIT-VI: MICROWAVE MEASUREMENTS: S-parameter measurements, Network analyzer, Spectral characteristics measurements, Spectrum analyzer, Phase noise measurement, Power measurement, Microwave
subsystem and system characteristics.

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 Ludwing and G. Bogdanov, RF Circuit Design: Theory and applications, Pearson Education,
Asia.
2. Lio SY, Microwave Devices and Circuits, Prentice Hall, India.
3. K.D Prasad, Antenna and wave propagation, Satyaprakash Publications, New Dehli.
4. Electromagnetic,John D. Kraus, Mcgraw-Hill.

LIST OF EXPERIMENTS

Sr. No.	Experiments
1.	Characteristics of Klystron Tube and to determine its electronics tuning range
2.	Practical and theoretical aspects of V-I characteristics of Gunn diode
3.	Determine the frequency and wavelength in a rectangular wave guide working on TE10 mode and determine the standing wave ratio and Reflection coefficient
4.	Functions of multi-hole directional coupler by measuring the following parameter a) Main line and Auxiliary line SWR b) Coupling factor and directivity c) Study of magic tee d) Study of circulator / Isolator e) Study of attenuator (Fixed and Variable Type)
5.	Working of Doppler Radar using Trainer Kit
6.	Radiation Pattern measurement of Antenna

Course Name: DIGITAL SIGNAL PROCESSING
Course Code: EE602

Course Outcome-

Course Outcomes	Description
CO1	Learn the basics of linear algebra, signal, and system.
CO2	Gain the theory of random variable, probability, and random process.
CO3	Acquire the basics of transforms such as Fourier transform, Laplace transform, and Hilbert transform
CO4	Learn the concept of Analog and digital filters

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, Eigen values and Eigen vectors, diagonalization, orthogonal diagonalization of symmetric matrices, singular value decomposition. **Signals:** classification of signals, continuous and discrete time signals, sampling theorem, sampling and reconstruction of continuous time signals, baseband and bandpass sampling, complex signal. **Systems:** LTI system, system properties, impulse response and system functions, FIR and IIR systems, convolution and correlation, linear convolution and circular convolution.

UNIT-II: PROBABILITY, RANDOM VARIABLE AND RANDOM PROCESS Randomness, axioms of probability, repeated trails, random variable, distribution and density function, conditional distribution and density, moments, characteristic function, one random variable, two random variable, correlation, covariance, independence, orthogonality, statistics, 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, Markov Chain.

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.
(Design and implementation of all techniques and algorithms studied in this course).

UNIT-IV: TRANSFORMS 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, overlap-add and overlap-save method.

UNIT-V: FILTERS Filters: analog and digital filters, FIR filter design, IIR filter design, and realization using direct, cascade and parallel forms, lattice structures.

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.

LIST OF EXPERIMENTS:

Sl. No	Experiment
1.	Introduction of Matlab/Simulink, Labview and its tool boxes

2.	Sampling and Reconstruction of signals
3.	Deterministic & Random Signal analysis using power spectral estimation techniques Period gram power spectral estimation technique PSD through correlogram technique 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 Name: WIRELESS AND MOBILE COMMUNICATIONS
Course Code: EE603

Course Outcomes:

CO-1	Basics of wireless communication, understanding of basic terms such as Bit error rate, symbol error rate, etc. and advantages and disadvantages of different wireless communication techniques.
CO-2	Basics of wireless channel modeling, Inter symbol interference, and Doppler fading.
CO-3	Introduction to cellular communication, understanding of frequency reuse, handover and various multiple access techniques.
CO-4	A detailed description of multiple access techniques, understanding of phenomenon such as reflection, refraction, scattering, and diffraction.
CO-5	Basics of RFID, understanding of Basic propagation channel in RFID, various near-field and far-field wireless techniques.

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, Intersymbol 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, Chipless RFID, NFC.

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. 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

REFERENCE BOOKS:
1. Introduction to Space Time Wireless Communications – Arogyaswami Paulraj –Cambridge University Press.
2. Digital Communications – John G Proakis – McGraw Hill Science/Engineering/Math.
3. Wireless Communications – Andreas Molisch – Wiley IEEE Press.
4. MobileWireless Communications – Mischa Schwartz – Cambridge University Press.

LIST OF EXPERIMENTS:

Sr. No.	**Experiments**
1.	Error Vector Magnitude Measurement for GSM Signal Objective i) To measure the error vector magnitude, occupied bandwidth, and channel power of a GSM modulated RF signal using an oscilloscope and the VSA software
2.	Spectrum Analysis of CDMA Signal Objectives i) To measure the channel power of a CDMA modulated RF signal using an oscilloscope and the VSA software ii) To perform an in-band limit test or spectrum emission mask test on a CDMA modulated spectrum
3.	Spectrum Analysis of GSM Signal Objectives i) To measure the spurious and harmonics of the GSM and CDMA modulated RF signal using an oscilloscope and the VSA software ii) To perform an out-of-band limit test that identifies the pass or fail level of the spurious and harmonics
4.	Occupied Bandwidth Measurement for GSM and CDMA Signals Objectives i) To measure the occupied bandwidth of a GSM and CDMA modulated RF signal using an oscilloscope and the VSA software ii) To determine the parameter that changes the occupied bandwidth

5.	Adjacent Channel Power Ratio Measurement for GSM and CDMA Signals Objective i) To measure the adjacent channel power ratio of the GSM and CDMA modulated RF signal using oscilloscope and VSA software
6.	Noise and Error Influence for GSM Signal Objective i) To measure the error vector magnitude of a GSM modulated RF signal with influence of noise and error using oscilloscope and VSA software

Course Name: RADAR SYSTEM DESIGN
Course Code: EE604

Course Outcomes:

CO-1	Analysis, design and development of RADAR transmitter receiver, and Antenna.
CO-2	Students will learn formulated RADAR equations for various types of RADARs (Bi-static, surveillance and static) and also understands the concepts of jamming.
CO-3	Students will acquire knowledge of RADAR cross section, clutter, atmospheric propagation and probability of false detection
CO-4	Students will be capable of applying their knowledge and skills to design RADAR transmitter and receiver.
CO-5	Students will be able to apply their knowledge and skills to simulate moving target RADARs, Measurement of Doppler shift, and other real time situations.

UNIT-I: INTRODUCTION TO RADAR - Basic principle of radar, Frequencies of operation, Classification of radars, their functionality and applications, Types of radar – CW, FMCW, Pulse Doppler, – principles and applications.

UNIT-II: RADAR PARAMETERS/DEFINITIONS - Radar Range, Cross Range and Doppler/Velocity measurements and Resolutions, Peak power, Average power and Duty Cycle, Target, Noise Power, Noise Power density, False Alarm, Concept of Detection.

UNIT-III: RADAR EQUATIONS: Derivation of the Basic Radar Equation, Point Target in Interference, Receiver Noise and Noise Bandwidth, Signal to Noise Ratio (SNR), 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-IV: RADAR CROSS SECTION (RCS) & THEORY OF DETECTION - Probability of Detection P_d,
Probability of False Alarm P_{FA} and Relation between P_d, P_{fa} and SNR-statistical phenomenon of Noise. Target characteristics- RCS, RCS fluctuation, Swirling Models, SNR deviation for fluctuating targets,

UNIT-V: CLUTTER – 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-VI: ATMOSPHERIC PROPAGATION - 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-VII: SURVEILLANCE AND TRACKING RADAR – 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.

RADAR DESIGNS; RADAR ELEMENTS' DESIGN

UNIT-VIII: RADAR TRANSMITTER 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.

UNIT-IX: RADAR ANTENNA DESIGN- 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-X: DUPLEXER/TR SWITCH & RADAR RECEIVER - Function and Characteristics, Types of Duplexer, 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

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.

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1	Generation of different Radar waveforms, Measurement of Doppler frequency shift, RCS measurement, Range measurement using Radar trainer kit.
2	Calculation of probability of detection for fluctuating targets, Modeling a pulse Doppler radar system, MIMO radar simulation using SystemVue tools.
3	Simulating moving targets, FMCW simulation using SystemVue.
4	Target cluster forming and range finding, Dead-zone marking and target detection using BFSR.
5	Target relative range/speed estimation, Realization of TWS using BFSR
6	Demonstration of the principle of IFF, Realization of Target position prediction using its data.

Course Name: NAVIGATION SYSTEM CONCEPTS
Course Code: EE605

Course Outcomes:

CO-1	Basics of navigation, position fixing, radio and satellite navigation, and terrestrial radio navigation, understanding of coordinate frames, kinematics, earth surface and gravity models.
CO-2	Understanding of satellite navigation, global positioning system, GNSSS, and detailed comparison between various navigation systems.
CO-3	Basic understanding of Multipath Mitigation, Signal Monitoring, Semi-Codeless Tracking, Radio Positioning Configurations and Methods.
CO-4	Basics of Aircraft Navigation Systems, Error Sources, Differential Loran, Ultra-wideband, Short-Range Communications Systems, Other Positioning Technologies, Receiver Hardware, and Antenna.

CO-5	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.

1. **Introduction to Navigation:** What Is Navigation, Position Fixing, Dead Reckoning, Inertial Navigation, Radio and Satellite Navigation, Terrestrial Radio Navigation, Satellite Navigation, Feature Matching, The Complete Navigation System.

2. **Navigation Mathematics:** Coordinate Frames, Kinematics, and the Earth: Coordinate Frames, Kinematics, Earth Surface and Gravity Models, Frame Transformations.

3. **GNSS: Fundamentals, Signals, and Satellites:** Fundamentals of Satellite Navigation, The Systems: Global Positioning System, GLONASS, Galileo, Beidou,
REGIONAL NAVIGATION SYSTEMS: Beidou and Compass, QZSS, 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

4. **Inertial Navigation:** Inertial-Frame Navigation Equations, Earth-Frame Navigation Equations, Local-Navigation-Frame Navigation Equations, Navigation Equations Precission, Initialization and Alignment, INS Error Propagation, Platform INS, Horizontal Plane Inertial Navigation, types of GYROS: Mechanical, Ring Laser and Fiber Optic, Accelerometers.

5. **Advanced Satellite Navigation:** Differential GNSS, Carrier-Phase Positioning and Attitude, Poor Signal-to-Noise Environments, Multipath Mitigation, Signal Monitoring, Semi-Codeless Tracking

6. **Principles of Radio Positioning:** Radio Positioning Configurations and Methods, Positioning Signals, User Equipment, Propagation, Error Sources, and Positioning Accuracy

7. **Terrestrial Radio Navigation:** Point-Source Systems, Loran, Instrument Landing System, Urban and Indoor Positioning, Relative Navigation, Tracking, Sonar Transponders

8. **Long- and Medium-Range Radio Navigation:** Aircraft Navigation Systems, Signals, User Equipment and Positioning, Error Sources, Differential Loran, Phone Positioning, Proximity and Pattern Matching, Ranging, Other Systems

9. **Short-Range Positioning**: Pseudolites, Ultra-wideband, Short-Range Communications Systems, Underwater Acoustic Positioning, Other Positioning Technologies

10. **Satellite Navigation Processing, Errors, and Geometry:** Satellite Navigation Geometry, Receiver Hardware and Antenna, Ranging Processor, Range Error Sources, Navigation Processor.

11. **Dead Reckoning, Attitude, and Height Measurement:** Attitude Measurement, Height and Depth Measurement, Barometric Altimeter, Depth Pressure Sensor, Radar Altimeter, Odometers, Pedestrian Dead Reckoning, Doppler Radar and Sonar, Other Dead-Reckoning Techniques: Image Processing, Landmark Tracking, Correlation Velocity Log, Air Data, Ship' s Log.

12. **Feature Matching:** Terrain-Referenced Navigation, Sequential Processing, Batch Processing, Performance, Laser TRN, Barometric TRN, Sonar TRN, Image Matching, Scene Matching by Area Correlation, Continuous Visual Navigation, Map Matching, Other Feature-Matching Techniques, Stellar Navigation, Gravity Gradiometry, Magnetic Field Variation.

13. **INS/GNSS Integration:** Integration Architectures, System Model and State Selection, Measurement Models, Advanced INS/GNSS Integration.

TEXT BOOK:

1. Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems, Paul D. Groves Artech House, 2008 and 2013 Second Edition.

REFERENCE BOOKS:

1. B. Hofmann Wollenhof, H. Lichtenegger, and J. Collins, "GPS Theory and Practice", Springer Wien, new York, 2000.

2. PratapMisra 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.

LIST OF EXPERIMENTS:

S. No.	Experiment	Objectives
1	Single satellite waveform	• Simulate single satellite with C/A code for GPS, IRNSS, GLONASS, Galileo, Beidou, SBAS (should include GAGAN) and QZSS • Specify the frequency channel, dynamic pattern: Static, constant velocity, constant acceleration
2	Multi satellite waveform	• Simulate multi-satellite signals • Constellation from GPS, GLONASS, QZSS, Galileo, Beidou
3	GPS, GLONASS, Galileo, Beidou, SBA Sa nd QZSS real time signal generation	• Simulate upto 15line-of-sightsatellitesforeach constellation: GPS L1C/A, GLONASS L1C/A, or Beidou B1, Gailleo, SBAZ, QZSS • Provide real-time control for individual satellites, including satellite on/off, absolute or relative satellite power, adding multipath, and applying a pseudo-range error.
4	Scenario generation and editing	• Create custom scenarios with your choice of location, date, time, and duration for either static and moving receivers
5	Satellite based augmentation system (SBAS)	• SBAS message editor to configure the SBAS message for PRN Mask, Fast Correction, Fast Correction Degradation Data Factor, Network Time, GPMask, Long Term Correction and Ionosphere Correction
6	Real time CW interference	• Should support adding multiple CW interference signal to real time GNSS signals within GPS, GLONASS or Beidou bands.
7	Real-time display	• Display the location of each satellite in sky-view to get real-time update of the satellite as its azimuth/elevation changes in time. • Bar view of real-time satellite power for all visible satellites. • Real-time receiver trajectory view to display the history trajectory of the playing scenario with detailed information on UTC, longitude, latitude, altitude, heading and velocity.

Course Name: STATISTICAL SIGNAL PROCESSING
Course Code: EE606

Course Outcome-

Course Outcomes	Description
CO1	Generalize the properties of statistical models in the analysis of signals using Stochastic processes. Students learned the forward and backword 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 Wavelet transform.
CO4	Applying knowledge and skills to visualize different type data/signals in time domain, frequency domain, and time-frequency domain. They are capable to design various type filters.

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, Wiener Filters for Filtering and Prediction, Summary and References, Problems.

UNIT III: LEAST-SQUARES METHODS FOR SYSTEM MODELING AND FILTER DESIGN.
System Modeling and Identification, Lease-Squares Filter Design for Prediction and Deconvolution, Solution of Least-Squares Estimation Problems, Summary and References, Problems.

UNIT IV: ADAPTIVE FILTERS.
Applications of Adaptive Filters, Adaptive Direct-Form FIR Filters, Adaptive Lattice-Ladder Filters, Summary and References, Problems.

UNIT V: 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 VI: WAVELT TRANSFORM FOR SIGNAL ANALYSIS
Continuous wavelet transform, 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. Compression, Gabor Wavelets for statistical signal processing.

UNIT VII FEATURE EXTRACTION AND STATISTICAL MODELS - Difference between Statistical and structural Characterisation, orientation histograms and co-occurrence matrices, convolutional models in range and angle, frequency domain model.

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.

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 noisy environment (AWGN level -5dB, 0dB, 5dB, 10dB, 20dB) and their frequency spectrum, time-frequency representation visualization.
3.	Simulation of analytic form of signal possesses (a) mono-component signal, (b) multicomponent signal.
4.	Design a FIR adaptive filter to remove different type noises from a natural signal such as physiological signals EEG, ECG, speech signals.
5.	Wavelet transform based case study

Course Name: DETECTION AND ESTIMATION THEORY
Course Code: EE607

Course Outcome-

Course Outcomes	Description
CO1	Learn basics of vector, matrices, bases functions, orthogonality SVD, EVD, SSA, PCA. Moreover the concept of ergodicity, PSD, covariance matrices, response of LTI system to random process, and spectral factorization are grasped.
CO2	Students got the concepts of the last-square methods for filter design, detection in 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. The 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 type data/signals in time domain, frequency domain, and time-frequency domain. They are capable to design various type filters.

UNIT-I: REVIEW OF VECTOR SPACES: Vectors and matrices: notation and properties, orthogonality and linear independence, bases, distance properties, matrix operations, eigenvalues and eigenvectors.

UNIT-II: PROPERTIES OF SYMMETRIC MATRICES: Diagonalization of symmetric matrices, symmetric positive definite and semi definite matrices, principal component analysis (PCA), and singular value decomposition.

UNIT-III: 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-IV: 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-V: ESTIMATION THEORY: Minimum variance estimators, Cramer-Rao lower bound, examples of linear models, system identification, Markov classification, clustering algorithms.

UNIT-VI: TOPICS IN KALMAN AND WEINER FILTERING: Discrete time Wiener-Hopf equation, error variance computation, causal discrete time Wiener filter, discrete Kalman filter, extended Kalman filter, examples.

TEXT/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.

LIST OF EXPERIMENTS:

Sl. No	Experiment
1	Introduction of Matlab/Simulink, Lab view and its tool boxes to simulate Signal models in the presence of various ambient Noise models (correlated/uncorrelated , White/Colored with Gaussian mixture models)

2	Target Signal & Ambient Noise Simulation (Scalar & Vector Sensor Array Data Vector Simulation):Generation of Multiple spatially separated targets in presence of Strong interferences and Additive Correlated/Uncorrelated, White/Colored Ambient Noise
3	Development of Detection Techniques for following cases 1. Constant amplitude Signal in AWGN 2. Time varying Known Signals in AWGN 3. Unknown Signals in AWGN
4	Development and performance comparison of the following Estimation techniques using a given signal & noise model (senor data model) - MLE, MMSE , Bays Estimator, MAP Estimator, Expectation Maximization (EM) algorithm
5	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 Name: MODERN WIRELESS COMMUNICATIONS
Course Code: EE608

Course Outcomes:

CO-1	Knowledge of modern wireless communication systems, understanding of basic terms such as signal to noise ratio, diversity, fading etc.
CO-2	Understanding of MIMO, Singular Value Decomposition, and beamforming.
CO-3	Knowledge of OFDM, OFDM-MIMO, and modulation techniques.
CO-4	Basic understanding of new wireless technologies such as 5G, NOMA, FBMC, Massive MIMO etc.
CO-5	Knowledge of various wireless standards.

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, mmWave, 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.

Text 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)

Reference Books/reports:

1. Theodore Rappaport, Wireless Communications, principles and Practices, 2nd Edition, Pearson.
2. 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.
3. Marco Di Renzo et. al, "Spatial Modulation for Generalized MIMO: Challenges, Opportunities and Implementation", Vol. 102, No.1, 2014.

Course Name: ANTENNA SYSTEMS
Course Code: EE609

Course Outcome-

Course Outcomes	Description
CO1	Understanding of 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	Design of planar antennas of various configurations

UNIT-I: 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.

UNIT-II: BASIC 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, WIRE ANTENNAS: Monopole, Dipole, Loop, Yagi Uda Antenna, Design of dipole and monopole antenna.

UNIT-III: ANTENNA ARRAYS - 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.

UNIT-IV: ARRAY SYNTHESIS AND BEAM FORMING -Schelkun off and Woodward Synthesis for beam formation. Binomial, Dolph- Tchebycheff and Taylor distribution arrays.

UNIT V: 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, Broad banding techniques. Printed Dipole and Monopoles – principles and broad banding techniques. Design a Rectangular, Circular and Trangular Patch Antennas.

UNIT VI: APERTURE ANTENNAS-Babinet -Brookner Theorm, 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.

UNIT VII: BROADBANDAND TRAVELLING WAVE ANTENNAS - Concept of Frequency Independent and Travelling Wave Antennas, Self-Complementary Antennas, Biconical Antenna, Log Periodical Antennas, Helical Antennas; Normal and Axial Mode, Spiral Antennas, Design of a Dipole Log Periodic Array and Helical Antenna.

UNIT VIII: ANTENNA MEASUREMENTS - Input impedance, Return Loss, VSWR, Bandwidth, Polarization, Radiation Patterns, Beam-width, Gain, Antenna Noise Power.

TEXT BOOKS:

1. Richard Poisel, Search Results Antenna Systems and Electronic Warfare Applications, Artech House.
2. Vijay Madisetti, Wireless, Networking, Radar, Sensor Array Processing, and Nonlinear signal processing,
CRC press....
3. 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.

LIST OF EXPERIMENTS

Sr. No.	Experiments
1.	Measure the functions of the front panel board keys' s of Vector Network Analyzer (VNAZVA40) for the frequency range from 10MHz to 40 GHz for measurement of various antenna parameters.
2.	Measurement of various parameters of antenna on VNA (i.e. Return loss, VSWR, gain, bandwidth, radiation pattern, E-palne and H-plane etc.)
3.	Radiation pattern measurement using DAMS controller and their connectivity to the antenna positioner inside the anechoic chamber and to the VNA.
4.	Measure and understood the antenna software which support to VNA, Antenna positioned and DAMS controller for "automated antenna measurement system".
5.	Delay measurement between two micro strip antennas using two port VNA ZVA40

Course Name: RADAR SIGNAL PROCESSING
Course Code: EE610

Course Outcome:

CO1	Gaining Knowledge on Mathematical interpretation & operation in Signals, Radar receiver & its components, DLC & its application & limitation, MTI & matched filter approximation.
CO2	Getting fundamentals of Pulse compression requirement & its technique. Radar based on pulse compression
CO3	Knowing Basics of tracking algorithms & its components & its limitation & advancement in technology. Different tracking Schemes
CO4	Knowing Basics of Beam forming for different types of target. Need of Photonic radar & its component & Application.
CO5	Students will be exposed to Signals & waveform techniques. Need of airborne radar. Understanding of Significance of Doppler frequency in radar application. Introduction to array & its advancement.

UNIT-I: RADAR SIGNALS AND NETWORKS: Real/Complex/Analytic Radar signal, Radar signal, Transmission of signal through network, signal representation using Fourier series, Spectra of few common Radar Signal, FT of DT sequence, Review of Impulse function/Deterministic/Random signal, random variable.

UNIT-II: RADAR SIGNAL PROCESSING CHAIN: Introduction, Radar receiver chain, derivation of

Doppler
frequency shift, N-pulse DLC, Moving Target Indictor (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-III: 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-VI: TRACKING ALGORITHMS: Kalman Filters, Manouver 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-V: 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.

UNIT-VI: AIRBORNE/SYNTHETIC APERTURE RADAR: Signal Processing, Waveform design – LPRF, MPRF, HPRF, 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.

UNIT-VII: ADAPTIVE ARRAY PROCESSING: Introduction, General array, linear array, Adaptive array processing, Non-linear beam forming (LMS, ALMS), sidelobe cancellers. Spatial filtering beam forming.

TEXT BOOKS:

1. Mark A. Richards, Fundamentals of radar signal processing, Tata MG 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.

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 pulse 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, Realization of digital and non adaptive beam forming, Adaptive array processing using LMS algorithm.
6	Modeling an adaptive digital beam former using, SAR simulation and Moving platform (airborne, space-borne and ship-borne) modeling using System Vue.

Course Name: ARRAY SIGNAL PROCESSING
Course Code: EE611

Course Outcome:

CO-1	Fundamentals of Array Signal Processing, Sampling Theorem, Frequency Domain and Uniform and non-uniform array
CO-2	Earth to Satellite linking and their calculations for losses.
CO-3	Concept of Beam forming and beamforming technologies.
CO-4	Compressed sensing, algorithms and measurement matrices study

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

Time delay beamforming, frequency domain beamforming, optimum beamformers: MVDR, MPDR, MMSE, Max SNR, LCMV, LCMP, GSC, mismatched beam former, eigenvector beamformer, beam space beamformer, broadband beamformer, adaptive beam formers: LMS and RLS.

UNIT – IV: DIRECTION OF ARRIVAL ESTIMATION

DoA estimation: ML, MAP, MUSIC, ESPRIT, for uncorrelated, correlated and coherent signals.

UNIT-V: COMPRESSED SENSING AND SPARSE SIGNAL PROCESSING

Introduction to CS, sparse representations: motivations and basic formulations, uniqueness of sparse representation. Measurement matrices: null space property, Restricted Isometry Property (RIP), Johnson Linden strauss Lemma, Random Matrices and RIP. Reconstruction algorithms: convex optimization methods, basis pursuit, basis pursuit demonising. Greedy algorithms: matching pursuit, orthogonal matching pursuit, subspace pursuit, compressive sampling matching pursuit.

REFERENCE 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, 21-Jun-2013

4. Compressed Sensing: Theory and Applications, Yonina C. Elda, Cambridge University Press

LIST OF EXPERIMENTS

Sl. No	Experiment
1	Introduction of Matlab/Octave to simulate spatially coherent signals in the presence of spatially and temporally correlated/uncorrelated noise
2	Signal & noise simulation, generation of multiple spatial signals in presence of strong interferences and additive noise
3	Conventional beam former via Delay & Sum technique Conventional beam former via Phase Shift based technique
4	Simulation of optimum beam forming: MVDR, MPDR, LCMV and LCMP
5	Performance comparison of beam formers in the presence of strong interferences and spatially correlated noise
6	Direction of Arrival estimation of a source in single and multiple sources scenario

Course Name: HIGH POWER MICROWAVE SYSTEMS
Course Code: EE612

Course Outcome:

CO-1	Introduction to High Power Microwave Systems and Microwave Fundamental Concepts
CO-2	Technological advancement in HPM and Microwave
CO-3	HPM Generation related structures and their studies
CO-4	Applications of HPM technologies in various areas.

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, multispectral sources.

UNIT-III: HPM TECHNOLOGIES: Introduction, pulse power, electron beam generation/propagation, pulse compression, diagnostics, computations technology, HPM facilities, beam less systems, UWB switching technologies, UWB systems and non-linear transmission line.

UNIT-IV: HPM SOURCES AND STRUCTURES: Introduction, design principle, operational features, R&D issues: Relativistic magnetron, 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.

TEXT BOOKS:

1. James Benford, John A. Swegle and EdlSchamiloglu ,High Power Microwave, CRC Press.
2. A. V. Gaponov-Grekhov, ,Granatstein .Victor LApplications of High-power Microwaves, Artech House.

REFERENCE BOOKS:

1. Victor L. Granatstein, ,Igor AlexeffHigh-power Microwave Sources, Artech House.
2. Robert J. Barker, EdlSchamiloglu, High-Power Microwave Sources and Technologies, Wiley.
3. R.A Cairns, ,Phelps .R.D.AGeneration and Application of High Power Microwaves, CRC Press.

Course Name: ELECTRONIC WARFARE
Course Code: EE613

Course Outcomes:

CO-1	Understanding of electronic defence, intercept system characteristic and functions.
CO-2	Knowledge of crystal video receiver, IFM receiver, super heterodyne receiver, channelized receiver, bragg cell receiver.
CO-3	Understanding of various types of jamming and ECM techniques.
CO-4	Basic understanding of Search radar counter-countermeasures and tracking radar counter-countermeasures.
CO-5	Knowledge of New electronic defence techniques and technologies trend.

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, probability of intercept.

UNIT-II: ELECTRONIC SUPPORT MEASURES

Typical ESM systems, sensitivity, receivers - crystal video receiver, IFM receiver, super heterodyne 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 COUNTER MEASURES
Principals 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, off-board ECM systems.

UNIT-IV: ELECTRONIC COUNTER-COUNTERMEASURES
Search radar counter-countermeasures, tracking radar counter-countermeasures.

UNIT-V: NEW ELECTRONIC DEFENSE TECHNIQUES
New electronic defense 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

TEXT 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.

REFERENCE BOOKS:
1. Electronic Warfare in the Information Age, 1999,D. Curtis Schleher, Artech House, Boston, London
2. Radar hand book, 1972/1990, Skolnik MI, Mc Graw Hill.
3. Fundamentals of Electronic Warfare, Artech House by Sergei A. Vakin

LIST OF EXPERIMENTS:

S. No.	Objectives
1.	Simulation of ESM techniques using Spectrum Analysers
2.	Simulation of ECM techniques using Signal Generators and Spectrum Analysers
3.	Simulation of direction finding techniques
4.	Location Estimation technique using GPS Receivers
5.	Simulation of noise cancellation techniques

Course Name: EMI/EMC DESIGN
Course Code: EE614

Course Outcomes:

CO-1	The effect 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.
CO-2	Understanding of EMI Instruments and testing, shielded structures and their functioning, Techniques to detect the EMI disturbances and ways of calibration, Design of EMI controlled circuitry.

CO-3	Knowledge of System level analysis and design of EMI controlled subsystems, Techniques to manage the ambient EMI and related concepts.
CO-4	Basic knowledge of different testing levels of EMI, their classification, experimental validation of EMI concepts, interpretation and inferences.
CO-5	working knowledge of EM modeling and simulation in an electromagnetic simulator, steps for designing and developing circuits and PCBs.

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.

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. Modules1- 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).
1. Electromagnetic compatibility management guide for platforms, systems and equipment, Standard Handbook, 1981 - Science - 125 pages, Pennsylvania State University.

LIST OF EXPERIMENTS:

S. No.	Experiments
1	Hands-On with EM Simulator (ADS/CST) **Objectives** i) Design and simulate RF circuits in EM simulator ii) Develop circuits through photolithography and measure the performance
2	Observe the Reflections after Terminating RF Cables/Planer Transmission Lines with Different Impedances **Objectives** i) Develop printed transmission lines on dielectric sheets ii) Measure the performance and compare with that obtained through simulations
3	PCB Board Level EMC Simulation **Objective** i) Observe the effects of shielding, grounding, etc. in EM simulator using appropriate probes
4	Controlling Crosstalk: Frequency-Domain Perspective **Objectives** i) To measure crosstalk in the frequency domain ii) To investigate the factors affecting the crosstalk level
5	Controlling Common Impedance Coupling **Objectives** i) To illustrate the effect of power supply noise on sensitive circuits ii) To illustrate the usage of decoupling capacitors and printed circuit board (PCB) layout in reducing power supply noise
6	Controlling Radiated Emission from Cable and PCB **Objectives** i) 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 spectrum analyzer ii) To learn some simple methods to reduce unwanted radiation using ferrite beads, grounding, and differential signaling
7	Transfer Impedance Measurement **Objective** i) To measure the transfer impedance of a coaxial cable as a function of frequency ii) To understand the importance of transfer impedance as a gauge of the shielding capability of a cable
8	Measure the EMI using EMI test receiver, LISN, EMI software's etc.
9	Measurement of frequency ranges of various EMI/EMC antennas and there various test range comparison to MIL-STD-461F
10	Different probes of EMI/EMC used to measure the EMI (for H-field, E-field), which is present in various electronic circuits and their frequency of operations.

Course Name: GNSS RECEIVER DESIGN AND APPLICATIONS
Course Code: EE615

Course Outcomes:

CO-1	Familiarize with applications as a function of GNSS receiver design
CO-2	Understanding basic concepts of GNSS receiver design and modifications for high sensitivity applications, high signal dynamic applications
CO-3	Analysis of GNSS receiver design and modifications for integration with other sensors.

CO-4	Knowledge of GNSS in advanced system level applications.

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.

UNIT-V: GNSS RECEIVER DESIGN AND MODIFICATIONS FOR INTEGRATION WITH OTHER SENSORS: Need for integration with other sensors and its merits case study of one integration concept Module.

UNIT-VI: INTRODUCTION OF GNSS IN ADVANCED SYSTEM LEVEL APPLICATIONS: Introduction and explanation of how GNSS is used in determination of attitude of a vehicle, precision farming, anti-collision techniques say in train and discussion on some new potential topics.

TEXT/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.

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1.	Simulation of Receiver Design and modifications for high sensitivity applications
2.	GNSS Receiver Design and modifications for integration with other sensors
3.	GNSS Receiver Design and modifications for high signal dynamic applications
4.	GNSS Receiver Design and modifications for high integrity applications Suggested

Course Name: MULTI SENSOR INTEGRATED NAVIGATION
Course Code: EE616

Course Outcomes:

CO-1	Familiarize with navigation system and introduction to integrated navigation types of Navigation
CO-2	Understanding basic concepts of estimation theory
CO-3	Analysis of linear systems & kalman filtering
CO-4	Knowledge of integrated navigation

UNIT-I: NAVIGATION SYSTEM AND INTRODUCTION TO INTEGRATED NAVIGATION TYPES OF 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: 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-III: LINEAR SYSTEMS & KALMAN FILTERING: Introduction to linear systems, Dynamic system 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-IV: 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,

TEXT 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

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1.	Using MATLAB program to check the (A) Controllability and (B) Observability of a system given by its state space model.
2.	Obtain a state-space representation of the system with given transfer function using MATLAB. 3. Obtain a transfer function of the system with given state-space representation using MATLAB. 4. Using MATLAB determines the state feedback-gain matrix K of a state space model given closed loop poles.
3.	Using MATLAB determine the observer gain matrix Ke of a state space model given closed loop poles.

Course Name: INERTIAL NAVIGATION SYSTEMS
Course Code: EE617

Course Outcomes:

CO-1	Familiarize with frames of references and inertial navigation fundamentals, concept of frames of references.
CO-2	Understanding strapdown inertial navigation computations sensor geometry, inertial navigation system alignment
CO-3	Analysis of navigation system simulation and error analysis error analysis
CO-4	Knowledge of advanced navigation concepts

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 ERROR ANALYSIS: development of perturbation models, attitude response under angular vibration, velocity response under combined angular and linear vibration, size effect errors, 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, gennav.

UNIT-VI: ADVANCED NAVIGATION CONCEPTS

Fundamentals of screw theory; fundamentals of Clifford algebra; dual quaternion and its applications in navigation.

TEXT 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

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1.	Use MATLAB to calculate the reliability of a TMR system if each component is having reliability R and only single module exist.
2.	Use MATLAB to calculate the measurement matrix of navigation sensors arranged in a skew symmetry given half cone angle.
3.	Use MATLAB to calculate the sensitivity of sensor errors.
4.	Use MATLAB to calculate the GDOP for sensor performance.
5.	Use MATLAB to calculate the PDOP for sensor performance.

Course Name: INDOOR NAVIGATION
Course Code: EE618

Course Outcomes:

CO-1	Familiarize with Location-Based Services (LBS), History of Navigation.
CO-2	Analyze Basic Positioning Techniques
CO-3	Building-modeling maps, Indor OSM, position refinement.
CO-4	Apply the knowledge of Simultaneous Localization And Mapping In Buildings, Case Studies

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, Lateration, Hyperbolic Lateration, 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:
Least Squares Estimation with Correlation, Recursive Least Squares Estimation, Discrete Kalman Filtering, The
Extended Kalman Filter, Particle Filtering, Grid-Based Methods, Sampling Importance Resampling.

UNIT-V:TRAJECTORY-COMPUTING:
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-VI:EVENT-DETECTION FOR INDOOR LBS:
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.

UNIT-VII: SIMULTANEOUS LOCALIZATION AND MAPPING IN BUILDINGS:
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

UNIT-VIII: OPEN PROBLEM SPACES (CASE STUDIES):
Open Problems in Prerequisites, Sensor and Timing Accuracy, Ambient Sensors and Building Automation, Basic Positioning Techniques, Building Modeling, Position Refinement, Trajectory Computing, Event Detection, Simultaneous Localization and Mapping in Buildings, Privacy and Security Considerations

TEXT BOOKS:
1. Indoor Location-Based Services Prerequisites and Foundations, Werner, Martin, Publisher: Springer;
2014 Edition ,ISBN-10: 3319106988

REFERENCE BOOKS:
1. Principles of GNSS, Inertial, and Multi-sensor Integrated Navigation Systems, Paul D. Groves Artech House, 2008 and 2013 Second Edition.
2. B. Hofmann Wollenhof, H. Lichtenegger, and J.Collins, "GPS Theory and Practice", Springer Wien, NewYork, 2000.
3. Pratap Misra and Per Enge, "Global Positioning System Signals, Measurements, and Performance,"
Ganga-Jamuna Press, Massachusetts, 2001.
4. Ahmed El-Rabbany, "Introduction to GPS," Artech House, Boston, 2002.
5. Bradford W. Parkinson and James J. Spilker, "Global Positioning System: Theory and Applications,"
Volume II, American Institute of Aeronautics and Astronautics, Inc., Washington, 1996.

LIST OF EXPERIMENTS:

Sr. No.	Objectives
1.	Single satellite- waveform by using WLAN or Signal generator or GPRS
2.	Multi-satellite waveform by using WLAN or Signal generator or GPRS
3.	Indoor Mapping using WLAN
4.	Scenario generation and editing- by using WLAN or Signal generator or GPRS
5.	Satellite based augmentation system (SBAS)- by using WLAN or Signal generator
6.	Real-time CW interference- by using WLAN or Signal generator
7	Real-time display- by using WLAN or Signal generator

Course Name: SOFTWARE DEFINED RADIO
Course Code: EE619

Course Outcomes:

CO-1	Familiarize with Software-Defined Radio and its various systems
CO-2	Analyze General-Purpose Processors and , Digital Signal Processors

CO-3	Classify Cognitive radio architecture, SDR architecture Applications of Cognitive radio, Spectrum sensing Single node sensing with its hardware platforms.
CO-4	Apply the knowledge and skills to Simulate SDR Flow in SystemVue, FPGA, GNU radio Simulation Software.

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, Tilera 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

TEXT BOOKS:

1. "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.
4. "Cognitive Radio, Software Defined Radio and Adaptive Wireless Systems", HüseyinArslan, Springer, ISBN 978-1-4020-5541-6 (HB), 2007.

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1.	Simulation of SDR Flow in SystemVue
2.	Simulation of SDR Flow in FPGA.
3.	Simulation of SDR/CR using GNU radio Simulation Software
4.	Study of Wideband and Narrow Band frequency allocations and applications /Signals using USRP
5.	Simulation of SDR Flow in SystemVue

Course Name: SoC AND EMBEDDED SYSTEMS
Course Code: EE620

Course Outcomes:

CO-1	To understand the memory interface concept and I/O interface concept in microprocessor and microcontroller.
CO-2	To understand the various device and buses and network protocol in the various processors
CO-3	To understand the DSP Processor , PSoc and CUDA platform for various application.
CO-4	To understand the fundamental of RTOS.

UNIT-I: INTRODUCTION: Definition and Classification, Overview of Processors and hardware units in an embedded system, Software embedded into the system, , Ebedded 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, 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, Instruction sets and programming Case Studies, Parallel Computing, CUDA platform for radar Application.

UNIT-IV: ADVANCED EMBEDDED COMPUTING: Programmable System on Chip, Cypress PSoC Technology. Advance 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-IV: 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, micro processors, memories, peripheral devices, interconnections Case study: VxWorks and RTLinux RTOS in computing systems: embedded system, real time system, parallel system, and distributed system

UNIT-V : Case Study: underwater gylider controller -Interfacing of various sensors such as inertial sensors and actuators using various processors and its performance comparison.

TEXT BOOKS:

1. ARM System-on-Chip Architecture (2nd Edition) Steve Furber.
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.

REFERENCE BOOKS:

1. http://www.xilinx.com/publications/xcellonline: Xcell Journal.
2. DSP Architecture, Programming and Application- B Venkataramani, M Bhaskar.
3. Wayne Wolf, Computers as Components; Principles of Embedded Computing System Design - Harcourt
India.

LIST OF EXPERIMENTS:

Sr. No	Experiment
Lab 1	Simulation of ALP using 8086 Emulator
Lab 2	FPGA programming using VHDL.
Lab 3	Radar signal generation using FPGA.
Lab 4	Creating a custom IP core using the IP Integrator in Vivado IDE
Lab 5	Recording and play back of audio signal using Zedboard DMA
Lab 6	Peripheral Module Interface using soft core processor Microblaze
Lab 7	PWM Applications using PSoC
Lab 8	Introduction to CUDA programming and Tesla Processors

Course Name: DIGITAL INTEGRATED CIRCUIT DESIGN
Course Code: EE621

Course Outcomes:

CO-1	Design of Combinational MOS Logic circuits
CO-2	Design of sequential MOS Logic circuits
CO-3	Develop the understanding of Large signal and small signal analysis of complex circuits.
CO-4	Develop the knowledge of Semiconductor memories
CO-5	Apply the knowledge for Simulation of circuits using PSpice and Microwind Backend Tools.

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 gate, 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.

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.

LIST OF EXPERIMENTS:

Sl. No	Experiment
Lab 1	Use of SPICE for MOSFET modeling and simulation of Digital combinational Circuits.
Lab 2	Schematic gate level Simulation of Digital combinational circuits
Lab 3	LVS simulation of Digital circuits.
Lab 4	Schematic gate level Simulation of Digital sequential circuits
Lab 5	Simulation of memory circuits using PSPICE

Course Name: RF IC DESIGN
Course Code: EE622

Course Outcomes:

CO-1	Generalize the basic concept/idea of RF transceiver, its design issues, linearity, non-linearity, and distortion. Students learned about device noise also.
CO-2	Students learned the basics of low noise amplifier, oscillator, and mixer.

CO-3	The concept of Gilbert mixer, single balanced mixer, and double balanced mixer, amplifier, and some part of power amplifier are given to students.
CO-4	Students will be capable of applying their knowledge and skills to design power amplifier, its use in transmitter, and multi-tier transceiver architecture.

UNIT I BASIC CONCEPT 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.

UNIT VI IMPLEMENTATIONS:
VLSI architecture for Multitier Wireless System - Hardware Design Issues for a Next generation CDMA System

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”, Cambridge University Press, 2003.
4. Emad N Farag and Mohamed I Elmasry, “Mixed Signal VLSI Wireless Design - Circuits and Systems”, Kluwer

Academic Publishers, 2000.
5.Behzad Razavi, "Design of Analog CMOS Integrated Circuits" McGraw-Hill, 1999.
6. J. Crols and M. Steyaert, "CMOS Wireless Transceiver Design," Boston, Kluwer Academic Pub., 1997.

LIST OF EXPERIMENTS:

Sl. No	Experiment
1	Characterization of Mixer using FieldFox
2	Characterization of LNA and Power Amplifier using FieldFox
3	Characterization of Frequency Synthesizers.
4	Simulation of LNA using ADS/Matlab Software.
5	Simulation of Power Amplifier using ADS/Matlab Software.
6	Simulation of Mixer using ADS Software.

Course Name: SEMICONDUCTOR DEVICES
Course Code: EE623

Course Outcomes:

CO-1	To understand the fundamentals of Semiconductor physics and junction Theory.
CO-2	To understand the concept of MOS capacitors and its Characteristics
CO-3	To understand the concept of BJT and HBT
CO-4	The future roadmap of the next generation of FET

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, IVcharacteristic, steadystate and transient conditions, capacitance model, reverse-bias breakdown, metalsemiconductor junctions -fabrication, Schottky barriers, rectifying ad ohmic contacts, I-V characteristics.

UNIT III: MOS Capacitors and MOSFETs: The MOS capacitor - fabrication, surface charge - accumulation, depletion, inversion, threshold voltage, CVcharacteristics - 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.

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.

LIST OF EXPERIMENTS:

Sl. No	Experiment
1	Use of SPICE for semiconductor modeling. Large signal and small signal modeling of PN Junctions
2	Schottky diode implementation in SPICE2
3	MOS Capacitor modeling in SPICE SPICE level 1, 2, and 3, and Berkeley short-channel IGFET modeling
4	I-V characteristics, Large Signal and small signal modeling of MOSFET
5	I-V characteristics, SPICE Modeling of BJTs and HBTs

Course Name: DIGITAL SYSTEM DESIGN USING FPGAs
Course Code: EE624

Course Outcome:

CO-1	Familiarized with the design of Combinational and Synchronous and Asynchronous Sequential Circuits. Gave an Overview of PLDs and PALs
CO-2	Covered basic introduction of VHDL and the basic language elements. Various Combinational and Sequential circuits were designed using VHDL
CO-3	In-depth analysis of Faults and testability in digital systems including modelling and detection
CO-4	Interfacing various sensors and reading/writing to/from various file formats. Implementing various modulation schemes
CO-5	Design of a RISC CPU, data and control path components. Introduction to various floating/fractional/fixed-point arithmetic operations. Implementing Data encryption/Decryption system, Error correction, communication modules, BERT

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.

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

LIST OF EXPERIMENTS:

SL No	NAME OF EXPERIMENTS
01.	The Basic FPGA Design Flow 1. To understand use of Xilinx ISE 2. To understand Xilinx Synthesis Technology or XST. 3. Familiarization of Xilinx Vivado Design Tools.
02.	Familiarization of FPGA Boards 1. Xilinx FPGA Boards (Virtex 6,Kintex7) 2.Implementation of Full adder, ALU , Memory and FIFO on FPGA
03.	Fault Detection Logic Implementation on FPGA 1. Stuck at Fault 2.Memory BIST
04.	Implementation of RISC CPU on FPGA and debugging using Embedded Logic Analyzers.

Course Name: HIGH PERFORMANCE DSP USING FPGA
Course Code: EE625

Course Outcomes:

CO-1	Understanding basics of system design and design tools like vivado, ISE etc. Also learning about the features of different FPGA boards.
CO-2	Learning different hybrid programming tools for system implementation like integration of MATLAB & Simulink, C & LABVIEW, etc. Learning IP core design for various DSP applications
CO-3	Learning to design algorithms for real-time DSP systems and different transforms. Also learning the applications of FPGA in modern technologies
CO-4	Learning FPGA hardware and using them for real-time experiments.

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

References:

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.

LIST OF EXPERIMENTS:

SL No	NAME OF EXPERIMENTS
01.	The Basic Design Flow of DSP Implementation in FPGA. 1. To understand use of Xilinx System Generator. 2. To understand Xilinx Synthesis Technology or XST. 3. Familiarization of Simulink, Signal Processing Toolbox, Signal Processing Block-set.
02.	Implementation of Dual Port RAMS, Addressable Shift Register, FIFO And ROM in FPGA.

	1. Familiarization with Memory Blocks implementation in FPGA. 2. To Understand FGPGA Hardware. 3. Familiarization of XUP board (Vertex-5).
03.	Implementation of M Code Adder in FPGA 1. This exercise provides an introduction to the integration of M Code into a System Generator System. 2. To understand functionality of a basic 2-input adder is interpreted from the M-code.
04.	Generation of Simulink System Period 1. To understand Simulink system periods, and confirm the meaning of this parameter from the simulation results.

Course Name: COMPRESSED SENSING AND SPARSE SIGNAL PROCESSING
Course Code: EE626

Course Outcome-

Course Outcomes	Description
CO1	Generalize the concept of compressed sensing.
CO2	Gain the theory of null space property and RIP.
CO3	Acquire the basics of convex optimization and basis pursuit.
CO4	Applying knowledge and skills to demonstrate in short project.

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: 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

UNIT-V: Applications: Classification.There can be a mini project for the course

TEXT 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

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1.	Simulation of algorithms in Matlab/Lab view. a. Basic Pursuit b. Matching Pursuit, c. Orthogonal Matching Pursuit, d. Subspace Pursuit, e. Compressive Sampling Matching Pursuit.

Course Name: SIGNAL THEORY, LINER ALGEBRA & TRANSFORM TECHNIQUES
Course Code: EE627

Course Outcome-

Course Outcomes	Description
CO1	Learn the basics of random variable, probability, density function, and correlation.
CO2	Gain the theory of Laplace transform, and 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.

UNIT I: 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 II: 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 III: 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.

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. Mecann, Harcourt Brace Jovancovich 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, Mc Graw Hill.

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1.	Simulation of the following techniques: a) Transform Techniques b) Z Transform c) Fourier Transform d) Wavelet Transform
2.	Gram-Schmidt orthogonalization for multiple wave forms
3.	Real time implementation Eigen values and singular values for speech signals

Course Name: ADVANCED ELECTRONICS SYSTEMS
Course Code: EE628

Course Outcome-

Course Outcomes	Description
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 application of RF Microelectronics.

UNIT -I: Introduction: Analog IC Design Flow -Digital IC Design Flow- Bipolar and CMOS Technology.

UNIT -II: Sensors and advanced topics: 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: Lab View (can be supported by laboratory).

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.

REFERENCE BOOKS:

1. Jan M. Rabaey; Anantha Chandrakasan; BorivojeNikoli´c, "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.

LIST OF EXPERIMENTS

S. No.	Name of the Experiments
01	Write VHDL programs for the a) Full Adder b) Multiplexer c) BCD-Gray code converter d) Shift Registers e) Barrel Shifters. Aim: 1. To understand the Various modeling such as a) data flow modeling b) behavioral modeling c) Structural modeling of VHDL. 2. Writing the test bench to create various stimulus for the DUT.
02	Implement the Booth Multiplier using structural modeling in FPGA. Aim: 1. To understand the Structural modeling of VHDL. 2. To understand the word length effects. 3. To understand the use of Xilinx ISE 16.1. 4. Hands on experience in SPARTAN 3E FPGA kits.
03	Implement a Traffic Light controller using Mealy Machine in FPGA. Aim: 1. To understand the Mealy State machine. 2. To understand the use of Xilinx ISE 16.1. 3. Hands on experience in SPARTAN 3E FPGA kits

04	Implement a Sequence Detector using Moore machine in FPGA. Aim: 1. To understand the Moore State machine. 2. To understand the use of Xilinx ISE 16.1. 3. Hands on experience in SPARTAN 3E FPGA kits.
05	Design an 8-bit Processor contain both combinational and sequential circuits to perform various arithmetic and logical operations. Aim: 1. To understand the mixed modeling styles of VHDL. 2. To understand the use of Xilinx ISE 16.1. 3. Hands on experience in SPARTAN 3E FPGA kits

Course Name: SONAR SIGNAL PROCESSING
Course Code: EE 629

Course Outcomes:

CO-1	To understand the basic of Sound and underwater channel models
CO-2	To understand the ambient Noise and radiated noise in the ocean
CO-3	To understand the refection and scattering by sonar targets
CO-4	To understand the shallow water acoustics and passive Sonar classifier.

UNIT-I: HISTORICAL BACK GROUND AND BASICS OF SOUND: History of sonar evolution, basics of sound measurement, measurement parameters, sound velocity profile and its variation, 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 there, impact on sonar performance. Sonar parameters, sonar equation for active and passive sonar.

UNIT-IV: RADIATED NOISE FROM MARINE VESSELS: Components of radiated noise, transmission of the components, propulsion types and their characteristics, ship design and stealth aspects.

UNIT-V: 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-VI: SHALLOW WATER ACOUSTICS: Deep Vs Shallow waters, Propagation in Tropical Littoral
Waters, Band limited Channel Characteristics, Fluctuations of a Shallow Water Underwater Channel.

UNIT-VII: PASSIVE SONAR CLASSIFIER: Feature Extraction, Feature Transformation, Acoustic Signature
Characteristics, Classification Algorithms, Practical Classifiers, Cepstral Features.

TEXT BOOKS:

1. Underwater Acoustic System Analysis, W S Burdic.
2. R. O. Nielsen, Sonar Signal Processing (Artech House, Boston, 1991).
3. Paul C. Etter, Underwater Acoustic Modelling and Simulation (Spon Press, Taylor and Francis Group,
London and New York, third edition, 2003).

LIST OF EXPERIMENTS:

Sr. No	Experiments
1	Introduction of Matlab/Simulink, Lab view and its tool boxes for simulating a single spatially coherent underwater acoustic signals in the presence of spatially and temporally correlated/uncorrelated noise (Simulation of hydrophone array data vector)
2	Target Signal & Ambient Noise Simulation (Scalar & Vector Sensor Array Data Vector Simulation): Generation of Multiple surface and subsurface targets in presence of Strong interferences and Additive Correlated/Uncorrelated, White/Colored, Gaussian/Non-Gaussian Ambient Noise Process.
3	Development of Conventional Direction of Arrival (DoA) estimation techniques for Passive & Active Sonar 1. Conventional Beam former Via Delay & Sum technique (Wideband Spatial Filter) 2. Conventional Beam former Via Phase Shift based technique (Narrowband Spatial Filter)
4	Development and performance comparison of the following High Resolution Adaptive Beam former techniques using Scalar sensor array & Acoustic Vector Sensor Array in Passive & Active Sonar:- MVDR, MPDR ,MUSIC, ESPRIT, Subspace Intersection Method (SIM), Generalized Side lobe Cancellation (GSC) Beam former
5	Performance comparison High resolution Passive & Active Sonar Signal Processing algorithms in the presence of strong interferences and Spatially Correlated Noise
6	Design & Development of STAP techniques to remove self-noise radiated from own ship. Compare the Passive Sonar performance with & without STAP.

Course Name: SONAR SYSTEM ENGINEERING
Course Code: EE630

Course Outcomes:

CO-1	To understand the SONAR Equation and its fundamentals.
CO-2	Array concepts and Beam forming in SONAR applications.
CO-3	Various Noise in SONAR
CO-4	Characteristics of Passive and Active SONAR

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 in sea water.

UNIT II: SONAR EQUATION- 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, Delayand-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 IN THE SEA- Propagation loss, Spreading losses, Absorption losses, Propagation in the real ocean, The 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.

UNIT VI: PASSIVE SONAR- 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.

UNIT VII: ACTIVE SONAR- Pulse Characteristics, CW Sonars, Reverberation Levels, Target Strengths, Echo Characteristics, Sediment Classification, Doppler.

TEXT BOOKS:

1. Principles of Underwater Sound, R J Urick, Third Edition 1983.
2. Sonar for Practising Engineers Third Edition by A. D. Waite; WILEY 2002.

Course name: SATELLITE COMMUNICATION
Course Code: EE63

Course Outcome:

CO-1	Introduction to Satellite Systems, learning of orbital systems and sub systems.
CO-2	Earth to Satellite linking and their calculations for losses.
CO-3	Satellite switching technologies
CO-4	Applications of direct satellites broadcasting like GPS and other mobile services

UNIT-I: OVERVIEW OF SATELLITE SYSTEMS, ORBITS AND LAUNCHING METHODS- Introduction, Frequency Allocations for Satellite Services, Intelsat, U.S. Domsats Polar Orbiting Satellites , Problems, 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 Nonspherical Earth , Atmospheric Drag , Inclined Orbits , Calendars , Universal Time , Julian Dates , Sidereal Time , The Orbital Plane , The Geocentric, Equatorial Coordinate System , Earth Station Referred to the IJK Frame , The Topcentric-Horizon Co-ordinate System , The Sub-satellite Point , Predicting Satellite Position.

UNIT II: GEOSTATIONARY ORBIT & SPACE SEGMENT- Introduction , Antenna Look Angels , The Polar Mount Antenna , Limits of Visibility , Near Geostationary Orbits , Earth Eclipse of Satellite , Sun Transit Outage , Launching Orbits , Problems, Power Supply , Attitude Control , Spinning Satellite Stabilization , Momentum Wheel Stabilization , Station Keeping , Thermal Control , TT&C Subsystem , Transponders , Wideband Receiver , Input Demultiplexer , Power Amplifier , Antenna Subsystem , Morelos , Anik-E , Advanced Tiros-N Spacecraft

UNIT III: EARTH SEGMENT & SPACE LINK- Introduction, Receive-Only Home TV Systems, Outdoor Unit, Indoor Unit for Analog (FM) TV, Master Antenna TV System , Community Antenna TV System , Transmit-Receive Earth Stations, Problems, Equivalent Isotropic Radiated Power, Transmission Losses, Free-Space Transmission, Feeder Losses, Antenna Misalignment Losses, Fixed Atmospheric and Ionospheric Losses, Link Power Budget Equation, System Noise, Antenna Noise, Amplifier Noise Temperature, Amplifiers in Cascade, Noise Factor, Noise Temperature of Absorptive Networks, Overall System Noise Temperature, Carrier-to-Noise Ratio, Uplink, Saturation Flux Density, Input Back Off, The Earth Station HPA, Downlink , Output Back off, Satellite TWTA Output, Effects of Rain, Uplink rain-fade margin, Downlink rain-fade margin, Combined Uplink and Downlink C/N Ratio, Intermodulation Noise

UNIT IV: SATELLITE ACCESS- Single Access, Preassigned FDMA, Demand-Assigned FDMA, SPADE System. Bandwidth-limited a Power-limited TWT amplifier operation, FDMA downlink analysis. DMA, Companion 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, Orbcomm.

Text 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.
Reference Books:
1. Timothy Pratt – Charles Bostian& Jeremy Allmuti, Satellite Communications, John Willy & Sons
(Asia) Pvt. Ltd. 2004
2. Wilbur L. Pritchars Henri G. Suyder Hond Robert A. Nelson, Satellite Communication Systems Engineering, Pearson Education Ltd., Second edition 2003.
3. Satellite Communications: Design Principles – M. Richharia, BS Publications, 2nd Edition, 2003

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1.	To set up a satellite communication link and study of change in uplink and downlink frequency
2.	Transmission of Audio and Video signals and Data Communication over satellite link
3.	Different GPS data like longitude, latitude and different types of dilute of precision using GPS receiver
4.	Selection of various PN codes like Gold, Barker and MLS in CDMA Technology
5.	Generation (spreading) and demodulation (dispreading) of DSSS modulated signal
6.	Minimum shift keying modulation and demodulation
7.	Determination of Maximum bit rate of a digital fiber optic link
8.	Demonstrating different modulation techniques with suitable demodulation
9.	Demonstrating different optical fiber losses
10.	Simulation of FSOC data link
11.	Atmospheric losses in FSOC
12.	Modeling and simulation of atmospheric attenuation and turbulence strength
13.	Demonstrating the beam steering system

Course Name: ADVANCED COMMUNICATION SYSTEMS
Course Code: EE632

Course Outcomes:

CO-1	Review of Fourier Transform, DTFT, Z-Transform, sampling theorem, PCM, DM, etc.
CO-2	Understanding of communication over AWGN channel, coding and equalization techniques
CO-3	knowledge of digital modulation and demodulation techniques.
CO-4	Knowledge of Signal & Noise Statistics in Coherent &Noncoherent Receivers.
CO-5	Basic understanding of source coding and entropies.

UNIT-1-Introduction: Block diagram of digital communication system, Review of Fourier Transform

properties,
Discrete Sequences, DTFT, ZT, 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-2-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-3-Modulation Techniques: Binary Baseband Digital Modulation Techniques, digital modulation techniques: ASK, BPSK, BFSK, DPSK, QPSK and M-ary signaling; M array 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-4-Demodulations Techniques: General Issues & Concepts, Matched Filters, Coherent Demodulation, Coherent Demodulation for Binary Wave Form, Coherent &Noncoherent Receivers for Orthogonal Signalling (OOK & FSK),

UNIT-5-Performance Analysis: 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-6-Information Theory techniques: 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

TEXT BOOKS

1. Sam Shanmugam, "Digital and analog communication system" , John Wiley,2005.
2. Herbert Taud, Donald L. Schiling, GoutamSaha, "Principles of Communication Systems" , - 3 rdEdition, McGraw - Hill2008.

3. Elements of Information Theory by Thomas Cover, Joy Thomas
4. Channel Codes: Classical and Modern by William Ryan, Shu Lin

REFERENCE BOOKS

1. Digital Communications -Simon Haykin, Jon Whiley,2005 2. Wayne Tomasi "Electronic communications systems" -5 thedition, pearson publication
2. Information Theory and Reliable Communication by Robert Gallager.

Course Name: UNDERWATER COMMUNICATIONS
Course Code: EE633

Course Outcome-

Course Outcomes	Description
CO1	Learn the basics of Underwater Acoustics-Underwater Communication Media, Underwater Systems and Networks,
CO2	Gain the theory 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.

UNIT-1: INTRODUCTION-Background and Context-Early Exploration of Underwater Acoustics-Underwater Communication Media, Underwater Systems and Networks,

UNIT-2: UWA Channel: UWA Channel Characteristics, Sound Velocity, Propagation Loss-Time-Varying Multipath-Acoustic Propagation Models-Ambient Noise and External Interference, Pass band 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-3: 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-4: MIMO-UWA: Multi-Input Multi-Output Techniques-Recent Developments on Underwater

Acoustic
Communications.

UNIT-5: 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

UNIT-6: PAPR CONTROL -PAPR Comparison-PAPR Reduction-Clipping-Selective Mapping-Peak Reduction
Subcarriers,

REFERENCES:

1. Shengli Zhou, Zhaohui Wang, "OFDM for Underwater Acoustic Communications", John Wiley & Sons
Ltd, 2014
2. Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung G. Kang, "MIMO-OFDM Wireless Communications with MATLAB", John Wiley & Sons Ltd, 2010

REFERENCE BOOKS:

1. Shengli Zhou, Zhaohui Wang, "OFDM for Underwater Acoustic Communications", John Wiley & Sons
Ltd, 2014
2. Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung G. Kang, "MIMO-OFDM Wireless Communications with MATLAB", John Wiley & Sons Ltd, 2010

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1.	Design and Simulation of conventional Underwater Communication techniques using Lab VIEW/Matlab
2.	Design, Simulate OFDM system using Lab VIEW/Matlab/ FPGA and Test the system over 'Air Acoustic Channel' using Speaker and mike
3.	Design, Simulate, MIMO-OFDM system using Lab VIEW- FPGA and Test the system over 'RF Channel' using LabVIEW NI USRP Platform
4.	Test the MIMO-OFDM system over 'Underwater Acoustic Channel' using acoustic transducer in a glass tank at the lab
5.	Test the MIMO-OFDM system over 'Underwater Acoustic Channel' using acoustic transducer in the Khadakwasla Lake

Course Name: MONOLITHIC MICROWAVE INTEGRATED CIRCUIT
Course Code: EE634

Course Outcomes:

CO-1	Understanding of planar technologies such as strip lines, microstrip lines, etc.
CO-2	Knowledge of microwave passive components such as branch line couplers, power dividers, circulators, phase shifters, etc.
CO-3	Understanding of microwave active circuits, stability and gain analysis through smith chart.
CO-4	Understanding of CAD techniques for oscillator, mixer designs.
CO-5	Knowledge of MMIC, hybrid MIC.

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 micro strip, Introduction to slot line and coplanar waveguide.

UNIT II: COUPLERS AND LUMPED ELEMENTS: PASSIVE DEVICES: Introduction to coupled micro strip, Evenand odd mode analysis, coplanar circuits, Design and fabrication of micro strip components: Branch line couplers, Filters, switches, attenuators, Directional couplers, lumped elements for169 MICs: Inductors, capacitors, resistors, multilayer techniques, Ferromagnetic substrates and inserts, Micro strip 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.

UNIT IV: HIGH &LOW POWER CIRCUITS: Introduction, Impedance transformers, Filters, High powercircuits, Low power circuits, MICs in Radar and satellite **AMPLIFIERS:** Stability & gain analysis, matching techniques, reactively matched amplifier design, LNA

UNIT V: OSCILLATORS: Design principles, active device CAD techniques for large signal oscillators design, Phase noise, MMIC_VCO, mixers.

UNIT VI: 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.

TEXT 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.

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1.	Impedance matching and S-Parameter analysis of : Coupled Transmission Line, Matching Transformers
2.	S-parameter analysis of : a) Power dividers b) Branch line couplers c) Rat race
3.	Filter design: Lumped to Micro strip Line transformation a) Low pass filter b) High Pass Filter c) Band Pass Filters d) Band Stop Filter
4.	Amplifier Design and Stability Analysis (Simulation using ADS/Matlab) a) Region of operation analysis b) Gain analysis c) Stability analysis using Smith Chart d) V-I characteristic and S-Parameter analysis
5.	Basic Oscillator Design and analysis using ADS/Matlab
6.	Design a complete single micro strip antenna for single frequency to verify the results
7.	Design different types of micro strip antennas and to verify the different results of these antenna

Course Name: INERTIAL SENSORS AND SYSTEMS
Course Code: EE635

Course Outcomes:

CO-1	Understanding the fundamentals of Navigation and Inertial Navigation, gyroscope working principle, different types of gyropscopes.
CO-2	Knowledge of configuration, working principle, design of serve accelerometers and its types.

CO-3	Knowledge of MEMS Inertial Sensors, and Testing of Inertial Sensors and Systems.
CO-4	Understanding of Inertial Navigation Systems, Gimbaled platform technology, Strap down INS realization etc.

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, Electro statically Suspended Gyro, Atom Interferometric Gyro etc.

UNIT III: 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.

UNIT VI: 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.

REFERENCE BOOKS:

1. Strap down Inertial Navigation Technology: by D. H. Titterton and J. L. Weston.
2. Modern Inertial Sensors and Systems: by Amitava Bose, SomnathPuri and Paritosh Banerjee.
3. Fundamentals of Navigation and Inertial Sensors: by Amitava Bose, K. N. Bhat and Thomas Kurian
4. AGARD-LS-95: Strap down Inertial Systems.

LIST OF EXPERIMENTS:

Sr No	Experiments
1.	Obtain an interference pattern using Michelson interferometer.(Basics for SAGNAC effect)
2.	Simulate DTG using MATLAB to calculate the rate
3.	Use MATLAB to plot the frequency response (BODE Plot) of DTG given by its closed loop transfer function
4.	Use MATLAB to calculate acceleration channel error model
5.	Use MATLAB to calculate rate channel error model

Course Name: NAVIGATION & AVIONICS SYSTEMS
Course Code: EE636

Course Outcome-

Course Outcomes	Description
CO1	Learn the basics of navigation method, 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 system, position and velocity determination.

UNIT-I: INTRODUCTION-Various navigation method, 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

UNIT-V: SATELLITE APPROACH AND LANDING AID- ILS, MLS, GLS - Ground controlled approach system surveillance systems-radio altimeter

UNIT-VI: SATELLITE NAVIGATION AND HYBRID NAVIGATION- Introduction to GPS system 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

UNIT-VII: RADAR NAVIGATION- 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.

TEXT BOOKS:

1. Myron Kyton, WalfredFried," Avionics Navigation Systems" John wliey& 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.

LIST OF EXPERIMENTS:

Sr. No.	Experiments
1.	Satellite Position fixing
2.	User position fixing using 3, 4 and 5 satellites
3.	DOPs Calculation
4.	Elevation and Azimuth angle Calculation
5.	Simulate of the following modulation schemes using MATLAB a. Amplitude Modulation, Frequency Modulation, Phase Modulation. b. Amplitude Shift keying, Frequency Shift Keying, Phase Shift keying.

Course Name: ASIC VERIFICATION USING SYSTEM VERILOG
Course Code: EE637

Course Outcomes:

CO-1	To understand the basic of System verilog- data types
CO-2	To understand the programming concept of System verilog
CO-3	To understand the verification tool by assertion coverage.

CO-4	Case study of Module verification by system verilog.

UNIT-I Introduction to functional verification languages, Introduction to System Verilog, System Verilog data types. System Verilog procedures, Interfaces and modports, System Verilog 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 in 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.

TEXT BOOKS:

1. "SystemVerilog for Design" : A Guide to Using SystemVerilog for Hardware Design and Modeling Sutherland, Stuart, Davidmann, Simon, Flake, Peter2nd 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. "Writing Test benches using System Verilog" Bergeron, Janick 2006,
2. "A Practical Guide for System Verilog Assertions" MeyyappanRamanathan

LIST OF EXPERIMENTS:

Sl. No	Experiment
1	1. Write an example to demonstrate the user defined data type enum, struct, struct packed, union, typedef and string. 2. Write an example to demonstrate the static array, multi-dimensional static array, dynamic array, associative array and queue type array. 3. Write an example to demonstrate a simple interface.
2	1. Write an example to demonstrate class constructor, inheritance, encapsulation, and polymorphism.

	2. Write an example to demonstrate randomization, rand casec, rand sequence, rand sequence abort. 3. Write an example to demonstrate DPI (Direct Programming Interface), both sv to c and c to sv. 4. Write an example to demonstrate semaphore, mailbox, virtual interface
3	1. Create SV based test environment for 1-bit adder. 2. Create class based test environment for 1-bit adder
4	1. Create a class based test environment for RAM memory given. 2. Create a class based test environment for FIFO memory given.
5	1. Create coverage and assertions for decade counter. 2. Create coverage and assertions for ones counter.
6	Create coverage and assertions for RAM memory previously created counter.
7	Create coverage and assertions for FIFO memory previously created counter.

Course Name: ANALOG AND MIXED MODE VLSI DESIGN
Course Code: EE638
Course Outcomes:

CO-1	Develop the knowledge of Device modeling of MOSFET
CO-2	Illustrate the concept of small signal analysis of single and multi-stage amplifiers
CO-3	Designing of switched capacitor circuits
CO-4	Demonstrate the Data convertors and its applications
CO-5	Lab- Simulation of circuits using PSpice and Microwind Backend Tools.

UNIT-I: INTRODUCTION AND BASIC MOS DEVICES: Challenges in analog design-Mixed signal layout issues-MOS FET structures and **characteristics**-large signal model -small signal model-single stage Amplifier-Source followerCommon 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 ADCPipeline 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

TEXT BOOKS:

1. VineethaP.Gejji Analog and Mixed Mode Design Prentice Hall, 1st Edition, 2011
2. JeyaGowri Analog and Mixed Mode Design Sapna publishing House 2011.
3. Gray Paul R, Meyer, Robert G, Analysis and Design of Analog Integrated Circuits, 3rd edition, John Wiley & Sons.
4. Jacob Baker, "CMOS Mixed-Signal circuit design", A John Willy & Sons, inc., publications, 2003.
5. Professor Bernhard Boser -" Analysis and Design of VLSI Analog-Digital Interface Integrated Circuits" "Addison Wisely publications" (1991).

REFERENCE BOOKS:

1. D A John, Ken Martin, Analog Integrated Circuit Design, 1st Edition, John Wiley
2. CMOS Analog Circuit Design, 2nd edition; by: Allen, Phillip E, Holberg , Douglas R, Oxford University Press, (Indian Edition
3. Ken Martin, Digital Integrated Circuit Design, John Wiley
4. Sedra& Smith, Microelectronics Circuits, 5th Edition, Oxford University Press, (Indian Edition)
5. Jan M. Rabaey, AnanthaChadrakasan, B. Nikolic ,Digital Integrated Circuits - A Design Perspective 2nd Edition, Prentice Hall of India (Eastern Economy Edition).
6. Sung-Mo Kang, Yusuf Leblebici, CMOS Digital Integrated Circuits Analysis & Design,2nd Ed, Tata McGraw Hill

LIST OF EXPERIMENTS:

Sl. No	Experiment
1	AN INVERTER: Schematic Entry and Symbol Creation Building the Inverter Test Design , Simulation with Spectre, Parametric Analysis ,Creating Layout View of Inverter ,Physical Verification ,Creating the Configuration View, Generating Stream Data.
2	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.
3	SRAM DESIGN: Schematic Entry and Symbol Creation Building the SRAM Test Design, Simulation with Spectre, Creating Layout View of SRAM, Physical Verification.
4	COMMON SOURCE AMPLIFIER: Schematic Entry and Symbol Creation Building the COMMON SOURCE AMPILFIER Test Design, Analog Simulation with Spectre.
5	DIFFERENTIAL AMPLIFIER DESIGN: Schematic Entry and Symbol Creation Building the DIFFERENTIAL AMPLIFIER DESIGN Test Design, Analog Simulation with Spectre.

6	BASIC OP AMP DESIGN: Schematic Entry and Symbol Creation Building the OP AMP Test Design, Analog Simulation with Spectre.
7	ADC Design: Schematic Entry and Symbol Creation Building the ADC Test Design , Simulation with Spectre.

Course Name: COMPUTER AIDED DESIGN OF VLSI CIRCUITS

Course Code: EE639

Course Outcomes:

CO-1	Develop knowledge about CAD tools used for digital VLSI design, digital logic simulation and physical design, including test and verification, develop understanding of FPGA CAD flow for design and implementation.
CO-2	Model digital systems at different levels of abstraction and simulate using verilog HDL,
CO-3	Develop understanding of automatic test program generation, testing algorithms, simulate and test circuits.
CO-4	Applying their knowledge and skills to model and synthesize logic circuits, do formal verification, transfer a design from a version possible to simulate to a version possible to synthesize

UNIT-I Various CAD Tools for front end and Back-end design, Schematic editors, Layout editors, 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 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.

TEXT BOOKS:

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", AddisonWeseley Longman Singapore Pte Ltd. 1992
3. Drechsler, R., *Evolutionary Algorithms for VLSI CAD*, Kluwer Academic Publishers, Boston, 1998.
4. Verilog HDL by Samir Palnitkar

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.

LIST OF EXPERIMENTS:

Sl. No	Experiment
1	Modelling and simulation of the following using Verilog Language and VLSI CAD Tools 1. Inverter 2. NAND GATE 3. Full adder 4.4-bit adder 5.4 bit counter
2	Modeling and Simulation of ALU using Verilog. Modeling and Simulation of FSMs using Verilog
3	Modeling and simulation of Memory and FIFO in Verilog
4	Simulation of NMOS and CMOS circuits using SPICE.
5	RTL to GDSII Generation 1. Inverter 2. NAND GATE 3.4-bit Counter
6	Modeling of MOSFET using C
7	ATPG Generation using CAD Tools.

Course Name: FPGA ARCHITECTURE AND APPLICATIONS
Course Code: EE640

Course Outcome:

CO-1	Understanding the architecture, programming and applications of various Programmable Logic Devices (PLDs).
CO-2	Fundamental knowledge on basic building blocks, routing architecture and design flow of Field Programmable Gate Arrays (FPGAs) and advanced FPGAs.
CO-3	Skills to design Finite State Machines (FSMs) based on state transition table and realization of various state machines.
CO-4	Gaining knowledge on usage of different FPGA tools for data path, front end and system level design using FPGAs.
CO-5	Skills on FPGA design considerations using sequential and combinational circuits and debugging using Logic Analysers.

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, parallel controllers. Debugging using Embedded Logic Analyzers.

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

LIST OF EXPERIMENTS:

Sl. No	Experiment
1	4 bit Counter: Design and porting of 4 bit counter on FPGA Platform(Xilinx/ALTERA)
2	Real Time Clock: Design and Implementation of Real Time Clock (RTC) on FPGA Platform.
3	ALU Design: Porting of an 8 bit ALU on FPGA Platform
4	FSM: Design and porting of Melay and More FSM (Sequence Detector) on FPGA
5	Clock Management Circuits: Implementation of Clock management circuits on FPGA.
6	IP Core Implementation: BRAMs, FFT IP, CORDIC etc.
7	Emulation: Typical RISC CPU Emulation on FPGA.

Course Name: VLSI SIGNAL PROCESSING
Course Code: EE641

Course Outcomes:

CO-1	Realisation of Algorithm in Data flow graph and Retiming and its applications
CO-2	Parallel processing and pipelining concept of FIR Filter
CO-3	Pipelining in Adaptive digital Filters
CO-4	Digital Arithmetic and Design of fixed point and floating point Adder and Multiplier

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 SoCs: State variable description of digital filters- Round off noise computation using state variable description- Scaling using slow-down, retiming and pipelining.

UNIT V: Digital arithmetic, Fixed point and floating point. Fixed point implementation of FIR filter. IEEE 754 Floating point standards, Floating point arithmetic operations. Design of floating point adder and multiplier.

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

LIST OF EXPERIMENTS:

Sl. No	Experiment
1	RTL Modeling and testing of Digital filters 1) FIR 2) IIR
2	RTL Modelling and testing of 8-point FFT algorithm. 1) Serial architecture implementation 2) Parallel architecture implementation
3	Pipelined FIR Filter design and implementation using HDL
4	Design and implementation of Fixed point IIR Filter
5	Floating point adder and multiplier design

Course Name: SOC DESIGN AND VERIFICATION
Course Code: EE642

Course Outcome-

CO1	Different approaches of chip design process and its requirements. Design issues, verification and test strategies.
CO2	Designing and developing of macro and the issues regarding designing it
CO3	Technology, Methods, languages, approach and plan for SOC verification on different levels.
CO4	Designing of communication architecture, design analysis. Need of adaptability of communication architecture. Understanding of base models.
CO5	Study of verification of design by using tools VMM, OVM and UVM

UNIT-I: SYSTEM ON CHIP DESIGN PROCESS: A canonical SoC Design, SoC Design flow waterfall vs spiral, topdown 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, Onchip 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.

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 Systemsonchips", A.A. Jerraya, W.Wolf, M K Publishers.
4. "The EDA Hand Book", Dirk Jansen, Kluwer Academic Publishers.

LIST OF EXPERIMENTS:

Sl. No	Experiment
1	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

Course Name -*Digital Interface Design*
Course Code- *EE 643*

Course Outcome:

CO-1	Students will be able to 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).
CO-2	Students will have Hands on experience/Knowledge on Sensor and Actuator Interface. They will also have the knowledge on various Sophisticated interfacing knowledge on Devices/Ports used in Robotics.
CO-3	Students will grow expertise on Data Convectors Interfacing. They will also be able to understand various specifications regarding robotics.
CO-4	Students will have working knowledge on Wireless and GPS interfacing. They will also be theoretically experienced on various Interfacing problems through case study.

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 Application. State Machines and applications.

Unit II: Sensor and actuator 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 convectors interfacing: Introduction to ADC and DAC. Various Types and **s**pecification. SPI interfacing in FPGA.

Unit IV: Wireless and gps interfacing: Introduction to Bluetooth- Zig Bee 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.

Text/References:

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.

LIST OF EXPERIMENTS:

Sl. No	Experiment
1	1. FPGA Interfacing Experiments a) LCD b) ADC
2	Motor Control and interface using PSoC
3	Case Study- underwater Glider and line follower Robot.

Course Name –*MIMO COMMUNICATIONS*
Course Code- *EE644*

Course Outcomes:

CO-1	Understanding of Modern multi-user communication technologies.
CO-2	Understanding of MIMO technology, coding, and diversity techniques.

CO-3	knowledge of channel estimation in massive MIMO and analysis with imperfect CSI.
CO-4	Basic Knowledge of new modulation schemes for 5G.
CO-5	Introduction to Cognitive radio technology, OFDM for CR, etc.

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-2: 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-3-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-4: Schemes for 5G: New Modulation Schemes for 5G: Spatial Modulation (SM), Space shift keying,
Generalized Spatial Modulation, Cooperative MIMO communication, Multi-Node Coopertaion, AF and DF
Protocols for Cooperation.

UNIT-5: 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.

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.
9. Recent technical publications.

Course Name –*ADVANCED DIGITAL SIGNAL PROCESSING*
Course Code- *EE 645*

Course Outcome-

Course Outcomes	Description
CO1	Learn the basics of Adaptive filters, MMSE, LMS, LS, and RLS.
CO2	Gain the theory of linear prediction, ARMA, and Kalman filter.
CO3	Acquire the basics of parametric and non-parametric methods.
CO4	Learn the idea of time frequency analysis.

UNIT-I: ADAPTIVE FILTERS- Non-stationary signal analysis, adaptive direct-form FIR filters, adaptive lattice-ladder filters, Minimum Mean Square Error (MMSE), Least Mean Square (LMS), Least Square (LS), RLS, QR decomposition, Levinson Durban method, Singular value decomposition, Given's rotation, Householder transform, Wiener filter. Optimization: gradient search algorithms and random search algorithms, gradient search by Newton's method and steepest descent method.

UNIT II: LINEAR PREDICTION- Forward and backward linear prediction, solution of the normal equations, properties of the linear prediction, prediction error, AR lattice and ARMA lattice, Wiener and Kalman filter for prediction. System modelling and identification.

UNIT-III: SPECTRAL ESTIMATION- Non-Parametric methods: estimation of spectrum from finite duration observation of signals, non-parametric methods: Bartlett, Welch and Blackman-Tukey methods, comparison of all methods.
Parametric methods: autocorrelation and its properties, relation between auto correlation and model parameters,
parametric methods: AR Models: Yule-Walker and Burg methods, MA and ARMA models for spectrum estimation.
Minimum variance spectral estimation, Eigen analysis for spectrum estimation.

UNIT-IV: MULTI RATE SIGNAL PROCESSING- Introduction, decimation by a factor D, interpolation by a factor I, sampling rate conversion by a rational factor I/D, multistage implementation of sampling rate conversion, filter design and implementation for sampling rate conversion.

UNIT-V: TIME-FREQUENCY ANALYSIS- Short time Fourier transform, Wigner Ville distribution, Wavelet transform: continuous wavelet transforms different wavelets and multiresolution analysis.

UNIT-VI: IMAGE PROCESSING

REFERENCE BOOKS:

1. Modern Spectral Estimation: Theory & Application – S. M. Kay, 1988, PHI.
2. Multi Rate Systems and Filter Banks – P. P. Vaidyanathan – Pearson Education.
3. Digital Signal Processing Handbook – Vijay K. Madisetti and Douglas B. Williams
4. DSP – A Practical Approach – Emmanuel C. Ifeacher, Barrie. W. Jervis, 2nd Ed., Pearson Education.
5. Digital Signal Processing: A Practitioner's Approach, Kaluri V. Rangarao, Ranjan K. Mallik ISBN: 978-0-470-
01769-2, 210 pages, November 2006.
6. Digital Signal Processing – S. Salivahanan, A. Vallavaraj, C. Gnanapriya, 2000, TMH.

Course Name: RF PHOTONICS
Course Code: EE647

Course Outcome-

CO-1	Understanding the fundamentals of microwave-photonics and brief idea of opto-electronic components (sources, modulators, receivers etc.)
CO-2	Learn about the photonic integrated circuits, tunable RF filters design, photonics based pulsed and FMCW RF exciter and multiband radar.
CO-3	Knowledge of microwave photonics signal processing like: filters, ADC, delay, sampling, photonic measurements, ultra-wideband free space beamforming etc.
CO-4	Understanding the concept of photonics-based broadband microwave measurements, signal parameter measurement-electric field, Phase Noise, Spectrum Analysis, Instantaneous Frequency and time-frequency analysis.
CO-5	Knowledge of full photonics radar, SAR/ISAR imaging, LIDAR systems, Fiber/FSO- connected Distributed Radar System.

1. 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.

2. RF signal generation and detection: Optoelectronic oscillators (generation, frequency combs); microwave photonic integrated circuits (different platforms of integration, filter designs, microresonators, nonlinear effects), photonic based tuneable 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.

3. 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,

4. 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.

5. 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 Name: VLSI FABRICATION TECHNOLOGY
Course Code: EE648

Course Outcomes:

CO-1	To understand the various materials in the Crystal Level.
CO-2	To understand the Ion Implantation, Diffusion and various fabrication process of IC
CO-3	To understand the thin film deposition and characterization techniques
CO-4	To understand the various process integration

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,

Diffusioncoefficients, Two-step diffusion, Diffusion system.
Thermal Oxidation: The Deal-Grove model, the initial oxidation, Oxidecharacterization, 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.

Reference Books

1: Stephen A. Campbell, The Science and Engineering of Microelectronic Fabrication, 2nd edition (Oxford University Press,2001).

List of Experiments:

1. Hands-on experience of deposition systems: sputtering system, chemical deposition system. Additionally, wafer processing for device fabrication.
2. Hands-on experience to structural measurement systems: XRD, Raman measurement.
3. Operation of Morphology Measurement Techniques: FESEM, TEM, and AFM.
4. Electrical characterization of the Semiconductor Devices: Hall Measurement, IV and CV.
5. Optical Characterization Techniques: UV-Vis Measurement, Spectroscopic Ellipsometry Measurement.

Course Name: Semiconductor devices for high speed and high-power applications.

Course Code: EE650

Course Outcomes:

CO-1	Understanding the performance parameters of high-speed devices and circuits, materials required for high-speed devices
CO-2	Understanding the fundamentals of physical phenomenons in MIS, MOS devices for high-speed applications
CO-3	Knowledge of HEMTS, HBTs
CO-4	Knowledge of latest technology in high speed and high power III-nitride HEMTs and its application various domains

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 PHENOMENON 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.

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.

List of Experiments:

1. DC characteristics of HEMTs
2. DC Characteristics of HBTs
3. Power amplifier design using HEMTs
4. Device physics of GaN HEMTs
5. LDMOS characteristics

Course Name: Quantum Transport in nanoscale FETs.

Course Code: EE653

Course Outcomes:

CO-1	Understanding the wave particle duality nature of electrons, enegy quantuzation, Hamiltonian etc.
CO-2	Understanding the Schrodinger equation, graphene structure self-consistent field (SCF) procedure for device simuations with quantum effects
CO-3	Knowledge of NEGF with scattering parameters for realistic nanotransistor simulations
CO-4	Knowledge of non-ideal effects present in nanoscale FETs, different types of scattering effects etc.

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.

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 McGrawHill, 2007.

List of Experiments:

1. Matlab coding and TCAD Simulations of NEGF Formalism
2. Modeling of GNR FETs
3. Quantum simulations of Tunnel FETs
4. Device physics, Subbands, Band diagrams study
5. Heterojunction lattice study

Department of Applied Chemistry

DEPARTMENT OF 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:
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 chemical technological challenges
- To provide an ability to function on multidisciplinary teams
- Thorough grounding and/or awareness and proficiency towards process safety as it pertains to process and unit design.

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.

M. Tech. in Nano Science & Technology

Semester I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	NT 601	Introduction to Nano Science & Technology	3	1	4
2	NT 602	Synthesis of Nanomaterials	3	1	4
3	NT 603	Nano materials for Energy and Environmental objectives	3	1	4
4	NT 604	Nanobiotechnology	3	1	4
5	NT 605	Characterization of Nano Materials	3	1	4
6	MM 606	Mathematics for Computational Materials Engineering	3	1	4
7	PGC 601	Research Methodology and IPR	2	0	2
		Total	**20**	**6**	**26**

Semester II

Sl. No.	Course Code	Course	Contact hours/week		Credits
			L	T/P	
1	NT 606	Nanotechnology for Defense and Industrial Applications	3	1	4
2	AP 610	Advanced Sensors	3	1	4
3		Elective – I [From Department of Applied Chemistry/ Phys/ Metallurgy & Materials Engg.]	3	1	4
4		Elective – II [From Department of Applied Chemistry/ Physics/ Metallurgy and Materials Engg.]	3	1	4
5		Elective – III	4	0	4
6		Elective – IV	4	0	4
7	PGC 602	Communication Skills & Personality Development	2	0	2
		Total	**22**	**4**	**26**

04 weeks of industrial practice school during summer vacation for scholarship students (**optional**)

Semester III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	NT 651	M. Tech. Dissertation Phase I	28		14
		Total	**28**		**14**

Semester IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	NT 652	M.Tech. Dissertation Phase II	28		14
		Total	**28**		**14**

❖ **For MM606 & AP610 please refer respective Department syllabus**

List of Electives/ Self Study

Sl. No.	Course Code	Course Name
1	NT 607	Nanotechnology in Devices
2	AC 608	Safety Health and Hazard Management
3	AC 609	NBC Warfare (Concepts & Remediation)
4	MM 610	Nanomaterials and their applications
5	MM 612	Polymer Blends and Nanocomposites
6	ME 636	MEMS - Design, Fabrication, and Characterization
7	AP 644	Nano photonics
8	Electives from other Department, MOOC/NPTEL courses	

<table>
<tr><td>Course Code</td><td>Course Name</td><td>L – T – P</td><td>Credits</td></tr>
<tr><td>NT-601</td><td>Introduction to Nano Science & Technology</td><td>3-0-2</td><td>4</td></tr>
<tr><td colspan="4">Course Objectives: The main objectives of this course are to:
1. To understand fundamental concepts of nanoscience and technology
2. To gain knowledge on size dependent various physical and chemical properties</td></tr>
<tr><td colspan="4">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, Physical Chemistry of solid surfaces, Confinement and transport in nanostructure.

UNIT IV: Nanoscale Phenomenon: Nanoparticles, nano-clusters, nanotubes, nanowires and nanodots. Electronic structure: quantum dots, quantum wires and quantum wells, confinement of electrons energy quantization semiconductor nanocrystals, carbon nanotubes, metal nanostructures, nanofluids, nanoink and hybrid nano materials and nano composites.</td></tr>
<tr><td colspan="4">Course Outcomes On the successful completion of the course, student will be able to:</td></tr>
<tr><td colspan="4">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 analyze the acquired knowledge and understanding on real time applications of various applications</td></tr>
<tr><td colspan="4">Reference Books</td></tr>
<tr><td colspan="4">1. Pradeep, T., Nano: The Essentials, McGraw Hill Publishers, Mumbai, 2007.
2. Charles P. Poole, Jr. Frank J. Owens, Introduction to Nanotech., John Wiley & Sons2003.</td></tr>
</table>

3. Vladimir V. Mitin, Viatcheslav A. Kochelap, Viacheslav Aleksandrovich KochelapIntroduction to Nanoelectronics: Science, Nanotechnology, Cambridge University – 2008
4. Pignataro, B., Tomorrow's Chemistry Today–Concepts in Nano science, OrganicMaterials, and Environmental Chemistry, Wiley-VCH, Royal chemical society, 2008
5. Howard, H., Into the Nano Era: Moore's Law Beyond Planar Silicon CMOS (Vol. 106),Springer Series in Materials Science, Springer-Verlag Berlin, 2004.

Course Code	Course Name	L – T – P	**Credits**
NT-602	**Synthesis of Nanomaterials**	3-0-2	**4**

Course Objectives: The main objectives of this course are to: 1.

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.

UNIT I: Fundamentals of nucleation and growth: Physical Chemistry of solid surfaces, Crystallization, Interactions between particles.

UNIT II: Top down and bottom-up approach of synthesis: Physical and Chemical routes, Physical Route for synthesis of Nanomaterials: Mechanical (high energy ball milling, melt mixing), physical evaporation methods (Plasma method, Pulse Laser method, spray pyrolysis), sputter deposition, Chemical Vapour Deposition, Arc Deposition, Atomic Layer Deposition.

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; Photochemical synthesis; Synthesis in supercritical fluids, Langmuir-Blodgett (LB) Method, Biological route of synthesis: using microorganisms, plant extracts, templates, etc.

UNIT IV: Self Assembly Route: Mechanism of Self Assembly, Some Examples of Self Assembly, Self-Assembly of Nanoparticles using Organic Molecules, Assembly in Biological Systems, Self-Assembly in Inorganic Materials, etc.

UNIT V: Large scale production of nanomaterials and examples.

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 evaluate and understand the role of preparation method towards grain with narrow distribution and desired morphology. **4.** To analyze acquired knowledge and understanding on effect of grain morphology and its needs for technological advancements
Reference Books
1. Suvardhan Kanchi, Shakeel Ahmed, Green Metal Nanoparticles, John Wiley & Sons 2018. 2. George Kyzas, Athanasios C. Mitropoulos, Novel Nanomaterials, Intechopen Limited- 2018. 3. G. Cao, Nanostruct. & Nanomaterials: Synth, Properties &Appl, ImperialCollege Press, 2004. 4. J.George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005. 5. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamentalanddevice applications, Cambridge University Press, 2001. 6. S.P. Gaponenko, Optical Prop. of semicond. nanocrystals, Cambridge Uni.Press, 1980. 7. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate(Eds.), Handbook of NanoScience,Engg.and Technology, CRC Press, 2002.

Course Code	Course Name	L – T – P	**Credits**
NT-603	**Nano materials for Energy and Environmental objectives**	3-0-2	**4**

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

UNIT I :- INTRODUCTION

Sustainable energy -Materials for energy -Greenhouse effect -CO2emission -Energy demand and challenges.

UNIT II:-RENEWABLE ENERGY TECHNOLOGY

Development and implementation of renewable energy technologies. Nano, micro and meso scale phenomena and devices. Energy conversion, transport and storage. High efficiency Photovoltaic solar cells. High performance thermoelectric systems -Integration andperformance of DSSC- Quantum dots based solar cells.

UNIT III:- NANOMATERIALS IN FUEL CELL AND STORAGE TECHNOLOGY

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.

UNIT IV:- HYDROGEN STORAGE AND PHOTOCATALYSIS

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 -degradation of the dye - nanomaterials based photocatalyst design -kinetics of degradation.

UNIT.V:- EMERGINGTECHNOLOGIES FOR ENVIRONMENTAL REMEDIATION

Use of nanoparticles for environmental remediation and water treatment-Role of dendrimer-single enzyme-nanoparticle and metalloprotein. Case studies and Regulatory needs.

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 environement

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, CRCPress, 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	L – T – P	Credits
NT-604	**Nanobiotechnology**	3-0-2	**4**

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 1) various definitions and Concept of Nano-biotechnology & Historical background. 2) Fundamental sciences and broad areas of Nano biotechnology. 3) Various applications of Nano-biotechnology 4) Cell – Nanostructure interactions

UNIT II: Biological nanoparticles production, surface functionalization- and their applications plantsand microorganism, Proteins, DNA based nanostructure

UNIT III: Devices based on nano biotechnology – and their applications, lab on a chip.

UNIT IV: Applications of Nanotechnology in Drug: Discovery and Delivery, bioinformatics

UNIT V: Nano materials for dental field and 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 BoscoGueguim-Kana, Nandita Dasgupta · 2021, Springer.

Course Code	Course Name	L – T – P	**Credits**
NT-605	**Characterization of Nano Materials**	3-0-2	**4**

1. To understand the basic analytical technical used for characterization of nanomaterials
2. To demonstrate and understand various spectroscopic techniques.
3. To distinguish various compositional and structural characterization techniques.

UNIT I:- 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 II: MICROSCOPY AND IMAGING:

Fundamentals of Imaging: magnification, resolution, depth of field and depth of focus, aberration and astigmatism, Optical microscopy, stereology basics and quantitative analysis, Basic principle and components of 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 and its applications, AFM

UNIT III: - SPECTROSCOPIC TECHNIQUES:

X ray Photon Spectroscopy, FTIR, Raman spectroscopy, UV-visible, PL

UNIT IV: THERMAL ANALYSIS TECHNIQUES: DSC, DTA, and TGA

UNIT V: OTHER TECHNIQUES: Dyanamic Light Scattering, Nano indentation, VSM, BET,Magnetic

Course Outcomes

1. To understand the processing and advanced microscope techniques.
2. To obtain knowledge on electrical and magnetic characterization techniques. To obtain knowledge on characterization techniques involved in Thermal
3. To understand the basic difference between thermal and non-thermal techniques

Text Books

Reference Books

1. Suvardhan Kanchi, Shakeel Ahmed, Green Metal Nanoparticles, John Wiley & Sons 2018.

2. Challa S.S.R. Kumar, Nanotechnology Characterization Tools for Tissue Engineering,SpringerNature – 2019.
3. Sverre Myhra, John C. Rivière, Characterization of Nanostructures, CRC Press – 2012.
4. Elements of X-ray Diffraction, B. D. Cullity, Prentice Hall, 2001
5. Materials Characterization, ASM Handbook Vol 10.
6. Characterization of Materials, Vol 1, Elton N. Kaufmann
7. Solid State Chemistry and its Applications, Anthony R. West, Wiley.

Course Code	Course Name	L – T – P	**Credits**
NT-606	**Nanotechnology for Defense and Industrial Applications**	3-0-2	**4**

1. To understand the role of nanomaterials for energy applications
2. To understand the role of nanotechnology in armor protective system
3. To understand the application of nano materials in industry

UNIT I: Introduction to nano-energetic materials; Applications of nano materials in ammunition,energetic materials, Nano-thermites.

UNIT II: Nanotechnology in stealth and armor protective system

UNIT III: Nano materials in thermoelectric and piezoelectric sensing

UNIT IV: Chemical and biological warfare: Nano materials in detection and decontamination ofCW and BW agents

UNIT V: 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 power of nano versed macro particles.
3. To understand how nanoparticles used in detection and decontamination of chemical and biological warefares.
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 Kosal · 2009, Springer

3. Nanotechnology in the Defense Industry: Advances, Innovations and Practical Applications,Madhuri Sharon, Angelica S. L. Rodriguez, Chetna Sharon, Wiley, 2019.

Course Code	Course Name	L – T – P	**Credits**
AC-608	**Safety, Health & Hazard Management**	3-0-2	**4**

Course Objectives:

1. undeerstand the principles of Standards and regulations of hazards management and peculiarities of their implementation.
2. Know prerequisites of the safety principles in management of modern organizations.
3. Be able to use these principles and methods in analyzing and solving problems of organization

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

UNIT II: HAZARD MANAGEMENT: HAZOP and HAZAN techniques, Hazard in manufacture, Hazard prevention measures, Disposal of hazardous materials

UNIT III: WARFARE: Classifications of explosives based on hazards, Nuclear, biological and chemical warfare safety.

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

UNIT V: PERSONAL PROTECTION

UNIT VI – MSDS for known/ unknown compounds.

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. Safety and accident prevention in chemical operations John Wiley and sons, New York

1982
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	L – T – P	**Credits**
AC-609	**NBC Warfare** **(Concepts & Remediation)**	3-0-2	**4**

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

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, Principle of operation of fission reactor, detectiontechniques of radiations.

UNIT III: NUCLEAR REACTORS

UNIT IV: 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

UNIT V: CHEMICAL & BIOLOGICAL WEAPONS: Different chemical warfare agents, Their tactical roles / effects, Delivery systems, biological warfare agents & their effects, Protection against biological, chemical warfare agents and their detection, decontamination of CW and BW agents.

UNIT VI : Biological

UNIT VII: Radiological weapon

Course Outcomes

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

Department of Metallurgical & Materials Engineering

M.Tech. in Materials Engineering

SEMESTER I

S.No.	Course Code	Course Name	Contact Hours			Credits
			L	T	P	
1	MM 601	Concepts in Metal and Ceramic	3	0	2	4
2	MM 602	Materials Characterization	3	0	2	4
3	MM 603	Thermodynamics of Materials	3	1	0	4
4	MM 604	Polymers and Composites Technology	3	0	2	4
5	MM 605	Physical and Mechanical Metallurgy	3	0	2	4
6	MM 606	Mathematics for Computational Materials Engineering	3	0	2	4
7	PGC 601	Research Methodology and IPR	2	0	0	2
		Total	20	1	10	26

SEMESTER II

S.No.	Course Code	Course	Contact Hours/week			Credits
			L	T	P	
1	MM 608	Fatigue, Fracture and Failure Analysis	3	1	0	4
2	MM 609	Materials Processing	3	0	2	4
3		Elective I (from Departmental Electives)	3	1	0	4
4		Elective II (from Departmental Electives)	3	1	0	4
5		Elective – III (from Open Electives)	3	1	0	4
6		Elective – IV (from Open Electives)	3	1	0	4
7	PGC 602	Communication Skills & Personality Development	2	0	0	2
		Total	18	6	0	26

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	MM 651	M.Tech. Dissertation Phase I	28		14
		Total	28		14

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	MM 652	M.Tech. Dissertation Phase II	28		14
		Total	28		14

List of Electives:

Sr. No.	Course Code	Electives from the Department
1.	MM 607	Design of Materials
2.	MM 610	Nanomaterial and Their Applications
3.	MM 611	Non-Destructive Evaluations
4.	MM 612	Polymer blends and Nanocomposites
5.	MM 613	Biomaterials
6.	MM 614	Introduction to Computational Materials Engineering
7.	MM 615	Magnetism and Magnetic Materials
8.	MM 616	Design of Materials
9.	MM 617	Materials for High -Temperature Applications
10.	MM 618	Advanced Steel Technology
11.	MM 619	Military Materials
12.	MM 620	Introduction to Corrosion
13.	MM 621	Welding Science and Technology
14.	MM 622	High temperature Corrosion
15.	MM 623	Corrosion mitigation
16.	MM 624	Advanced Coating
17.	MM625	Surface Science and Engineering
18.	MM 626	Reliability Engineering
19.	MM 627	Electrical and Electronic Materials

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.

➢ **Course Structure:**
Course Name: Concepts in Metal and Ceramic
Course Code: MM 601

Course Outcomes (CO):	
CO-1:	Understanding classifications and characteristics of materials
CO-2:	Analysis and properties of crystalline materials
CO-3:	Detailed overview of ceramics and their characteristics
CO-4:	Cognizance of dielectrics, refractories and their applications
CO-5:	Demonstration of Solid state, Sol-Gel, Hydrothermal and Co-precipitation process

	Syllabus Details
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
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. Glass: Definition of glass, Basic concepts of glass structure, Different types of glasses. Application of glasses.
Unit V	Practical: Solid state, Sol-Gel, Hydrothermal and Co-precipitation process

Textbooks

- *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: VanVlack*
- *Handbook of Ceramics: Editor S. Kumar Ceramic*
- *Materials for Electronics: R.C. Buchanon*

Course Name: Materials Characterization
Course Code: MM 602

Course Outcomes (CO):	
CO-1:	Illustrate the diffraction techniques and its interpretation.
CO-2:	Described several microscopy instruments and their imaging fundamentals
CO-3:	Summarized spectroscopy techniques and their applications
CO-4:	Understanding of thermal analysis techniques
CO-5:	Hands on experience of microscopy techniques and corrosion methods.

	Syllabus Details
Unit I	Diffraction Techniques- Concepts of diffraction, scattering and radiation-matter interactions, X-ray diffraction: phase identification, strain and grain size determination
Unit II	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, STM and AFM
Unit III	Spectroscopic Techniques- Fundamental basis of Spectroscopic analysis EDS and WDS applications, X-ray Photoelectron Spectroscopy and Auger electron spectroscopy

Unit IV	Thermal Analysis Techniques- DSC, DTA, TGA and Dilatometry, Electrochemical polarization characterization, Electrochemical Impedance spectroscopy.
Unit V	Practical: XRD, TEM, SEM, Cyclic voltammetry, Tafel plot, and Salt Spray, weatherometer, cyclic corrosion test, cathodic protection monitoring, localised corrosion monitoring methods (SECM, SEVT)

Textbooks

- *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 Name: Thermodynamics of Materials
Course Code: MM 603

Course Outcomes (CO):	
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

	Syllabus Details
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

Textbooks

- *David R. Gaskell, Introduction to the Thermodynamics of Materials, Taylor & Francis, 1798*
- *Ahindra Ghosh, Textbook of Materials and Metallurgical thermodynamics. Prentice Hall of INDIA 2003*

Reference Book(s):

- *R.T. DeHoff, Thermodynamics in Materials Science, McGraw-Hill, Singapore, 1993*
- *D. A. Porter and K. E. Easterling, Phase transformations in Metals and Alloys, Chapman and Hall, London, 1996*
- *Taiji Nishizawa, Thermodynamics of microstructures, ASM International*

Course Name: Polymer and Composite Technology
Course Code: MM 604

Course Outcomes (CO):	
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

	Syllabus Details
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, 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

Textbooks

- *V.R. Gowariker, Polymer Science, Wiley Eastern, 1995*
- *F. N. Billmeyer, Textbook of Polymer Science, Wiley Interscience, 1971.*

Reference Book(s):

- *Kumar and S. K. Gupta, Fundamentals and Polymer Science and Engineering, Tata McGraw-Hill, 1978*
- *Epel, J.N.:Engineering Plastics, Engineering Materials Handbook, ASM International 1988.*
- *Brydson, A.J. : Plastics Materials, Princeton, N.J., 1966*

Course Name: Physical and Mechanical Metallurgy
Course Code: MM 605

Course Outcomes (CO):	
CO-1:	Identify the defects in metals and phases in Fe-FeC diagram with TTT and CCT diagrams
CO-2:	Analysis of defects transfer in crystal structure
CO-3:	Conception of several strengthening mechanisms
CO-4:	Cognizance of strength testing in materials and dependent phenomenon
CO-5:	Case studies of metallurgy testing techniques

	Syllabus Details
Unit I	Crystal defects/imperfection in Metals, dislocations, burger vectors, dislocations multiplications, dislocation interactions, stacking faults, Phase rule, Phase diagram, Eutectic, Fe-FeC diagram, TTT and CCT diagrams for carbon steel
Unit II	Plastic deformation in single crystal, critical resolved shear strength, deformation
Unit III	Strengthening mechanisms: Solid solution strengthening, strengthening from grain boundaries, strains hardening, strain ageing, annealing of cold worked materials, strengthening from particles, precipitation hardening
Unit IV	Hardness and tensile testing, stress-strain relationships, effect of strain, strain rate and temperature on flow stress, nanoindentation, High temperature deformation and Creep, Superplasticity
Unit V	Practical: Metal Polishing and Etching, Optical Microstructural Characterization, Wear and friction, hardness testing

Textbooks

- *Mechanical Metallurgy, G.E. Dieter, McGraw-Hill book company, 1988*

Reference Book(s):

- *Mechanical behaviour of Materials, Williams F Hosford, Cambridge University press, 2005*
- *Materials Science and Engineering by William D. Callister, John Wiley& Sons, Inc.*
- *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*
- *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.*

Course Name: Mathematics for Computational Materials Engineering
Course Code: MM 606

Course Outcomes (CO):	
CO-1:	Understand the basics of programming
CO-2:	Recognize the principles of data-driven modelling
CO-3:	Implement the analytical and numerical solution to partial differential equations utilised in Materials Engineering
CO-4:	Analyze the mesoscopic modelling techniques
CO-5:	Utilise the principles of modelling and simulation to evaluate properties

	Syllabus Details
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	Evaluation of properties from the computed microstructures using mean field and full field approaches; data analytics using principal component analysis; ICME approach

Textbooks

- *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.*

Course Name: Design of Materials
Course Code: MM 607

Course Outcomes (CO):	
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 transformations processes
CO-4:	Understanding ceramics and statistics of brittle fracture
CO-5:	Demonstration of Solid state, Sol-Gel, Hydrothermal and Co-precipitation process

	Syllabus Details
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.

Textbooks

- *Engineering Materials 1 Michael F. Ashby and David R. H. Jones; Butterworth- Heinemann, Elsevier Publications*
- *Engineering Materials 2 Michael F. Ashby and David R. H. Jones; Butterworth- Heinemann, Elsevier Publications*

Reference Book(s):

- *D. A. Porter and K. E. Easterling, Phase transformations in Metals and Alloys, Chapman and Hall, London, 1996*
- *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*

Course Name: Fatigue, Fracture and Failure Analysis
Course Code: MM 608

Course Outcomes (CO):	
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

	Syllabus Details
Unit I	Stress cycles, Interpretation of Fatigue Data. Endurance Limit, Effect of Mean Stress on Fatigue, Cyclic Stress-Strain Curve, Low Cycle Fatigue, Plastic Strain & Fatigue Life,
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.

Textbooks

- *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.*

Reference Book(s):

- *Deformation and fracture mechanics of engineering materials, 4th Ed., R. W. Hertzberg, John Wiley & Sons, 1995.*
- *Elementary engineering fracture mechanics By David Broek Noordhoff 1974.*
- *Fatigue and Fracture of Metals, W. M. Murray, John Wiley, 1952.*

Course Name: Materials Processing
Course Code: MM 609

Course Outcomes (CO):	
CO-1:	Understand the processing of polymers
CO-2:	Analyse the processing of ceramics
CO-3:	Comprehend the processing of metals
CO-4:	Identify the metal forming processes
CO-5:	Demonstration of various processing units

	Syllabus Details
Unit I	**Processing of Polymers**- Extrusion, compounding, fiber spinning, injection moulding, compression moulding, Additive manufacturing
Unit II	**Processing of ceramics**- Compaction, moulding, sintering, refractory manufacturing processes, glass manufacturing techniques.
Unit III	**Processing of Metals**- Casting, Hot working, Cold working, Rolling, Annealing, Forging, Extrusion,
Unit IV	Wire drawing, Sheet metal forming, Joining Techniques, Friction stir welding, Powder Metallurgy
Unit V	Practical: Metal processing- rolling, annealing; polymer processing-Extrusion and compression molding, electrospinning

Textbooks

- *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986.*
- *Manufacturing Processes and Materials for Engineers, L. E. Doyle, 1975. Powder*

Reference Book(s):

- *Metallurgy, Applications, Advantages and Limitations, Klar, Erhard, ASM, 1983, Ohio.*
- *Plastics Processing Data Handbook (2nd Edition), Rosato, Dominick, 1997.*

- *Plastic Injection Molding: Manufacturing by Douglas M. Bryce, 2007.*
- *Concise encyclopedia of plastics, Rosato, Marlene G, 2005*
- *Extrusion: the definitive processing guide and handbook, Giles, Harold F.; Wagner, John R.; Mount, Eldridge M, 2005.*

Course Name: Nanomaterial and Their Applications
Course Code: MM 610

Course Outcomes (CO):	
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

	Syllabus Details
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, 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.

Textbooks

- *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: Non-Destructive Evaluations
Course Code: MM 611

Course Outcomes (CO):	
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

	Syllabus Details
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.

Textbooks

- *Non-destructive Testing of welds, Baldev Raj, C.V. Subramanian and T. Jayakumar, Narosa Publishing House, 2000, Delhi.*

Reference Book(s):

- *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 Name: Polymer Blends and Nanocomposites
Course Code: MM 612

Course Outcomes (CO):	
CO-1:	Detailed introduction to polymer blends and nanocomposites with miscible and phase separated thermodynamic aspects
CO-2:	Classified polymer blends and composites
CO-3:	Conception of nanostructured materials and interface of reinforced materials
CO-4:	Demonstrated several processing methods for polymer blends
CO-5:	Case studies of polymer nanocomposites in defence applications

	Syllabus Details
Unit I	Introduction to polymer blends and composites, nanostructured materials and nanocomposites Thermodynamical 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	Potential Applications in Defence.

Textbooks

- *Textbook of Polymer Science, Fred W. Billmeyer (Wiley)*
- *Polymer alloys and blends by L A Utracki*

Reference Book(s):

- *Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)*

Course Name: Biomaterials
Course Code: MM 613

Course Outcomes (CO):	
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

	Syllabus Details
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

Textbooks

- *Biomaterials- An Introduction, Joon Park- Publisher Springer*

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 Hall*

Course Name: Introduction to Computational Materials Engineering
Course Code: MM 614

Course Outcomes (CO):	
CO-1:	Understand the basics of programming
CO-2:	Recognize the principles of data-driven modeling
CO-3:	Implement the analytical and numerical solution to partial differential equations utilised in Materials Engineering
CO-4:	Analyze the mesoscopic modelling techniques
CO-5:	Utilise the principles of modelling and simulation to evaluate properties

	Syllabus Details
Unit I	Review of programming in high level languages such as Python / MATLAB / Mathematica and low-level languages such as C / C++ / Fortran
Unit II	Fitting and visualization of multidimensional data; Quantification of experimental microstructures using programs as well as software tools
Unit III	Application of linear algebra towards solution to a system of linear and nonlinear equations; Numerical integration; Numerical solution of diffusion equation;
Unit IV	Computational techniques such as phase field method and Monte Carlo towards evolution of microstructure; synthetic microstructures
Unit V	Evaluation of properties from the computed microstructures using mean field and full field approaches; data analytics using principal component analysis; ICME approach

Textbooks

- *Introduction to Computational Materials Science – Richard LeSar, Cambridge University Press (2013). ISBN: 9781316614877*

Reference Book(s):

- *Mathematical Methods for Physics and Engineering, 3rd Edition – R.F. Riley, M.P. Hobson, S.J. Bence, Cambridge University Press (2012). ISBN: 9780521139878*
- *Integrated Computational Materials Engineering (ICME) for Metals – Mark F. Horstemeyer, TMS (2012). ISBN: 9781118022528*

- *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*

Course Name: Magnetism and Magnetic Materials
Course Code: MM 615

Course Outcomes (CO):	
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

	Syllabus Details
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: TERFNOL-D, Multiferroics, Magnetic Anomaly Detection.

Textbooks

- *Introduction to Magnetic Materials, B. D. Cullity and C. D. Graham; IEEE Press, A. Jon Wiley & Sons Publications*

Reference Book(s):

- *Fausto Florillo, Measurement and Characterization of Magnetic Materials, Elsevier Academic Press, 2004*
- *Modern magnetic Materials: Principles and applications Robert C. O□Handaley; Wiley-Interscience Publications*
- *Physics of magnetism and Magnetic materials*
- *K. H. J. Bushaw and F. R. de Boer; Kluwer Academic Publishers*

Course Name: Heat-treatment of Metals and Alloys
Course Code: MM 616

Course Outcomes (CO):	
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

	Syllabus Details
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 Aluminum, Titanium and Magnesium Alloys
Unit V	Deformation and annealing.

Textbooks

- *Heat Treatment Principles & Techniques, TV Rajan, CP Sharma & Ashok Sharma Prentice Hall of India, New Delhi, 2007.*
- *Metallurgy for Engineers-EC Rollason, 4th Ed, Edward Arnold, UK, 1973.*
- *Introduction to Physical Metallurgy, S H Avner, TATA Mc-Graw Hill, New Delhi, 2001.*

Reference Book(s):

- *Engineering Physical Metallurgy by Yuri Lakhtin, Moscow, MIR Publishers, 1963.*
- *Grain boundary migration in metals: thermodynamics, kinetics, applications, G. Gottstein & L. Shvindlerman, Boca Raton (FL), CRC, 1999.*

Course Name: Materials for High -Temperature Applications
Course Code: MM 617

Course Outcomes (CO):	
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:	Case study 1: High speed steels: their application, process and properties
CO-4:	Case study 2: Ni based Superalloys as aero-engine applications, their structures and processing
CO-5:	Identified advanced structural ceramics for high temperature application

	Syllabus Details
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
Unit V	Processing and properties of advanced Structural Ceramics

Textbooks

- *Superalloys, supercomposites and super ceramics, ed. J. K Tien and T. Caulfield, Academic Press, 1989, Boston.*
- *High temperature structural materials, R. W. Cahn, Chapman and Hall, 1996, London.*

Reference Book(s):

- *Materials for High Temp. Engg. Applications, G. W. Meetham and M.H. Van de Voorde, Springer, 2000, Berlin.*
- *Friction, wear and Lubrications, K.C. Ludema, CRC Press, 1996.*
- *Powder Metallurgy: Science, Technology, and Materials Anish Upadhyaya and G. S. Upadhyaya, Taylor & Francis, 2011*

Course Name: Advanced Steel Technology
Course Code: MM 618

Course Outcomes (CO):	
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

	Syllabus Details
Unit I	Strengthening mechanisms: Work hardening, Solid solution strengthening, Grain size refinement, Dispersion strengthening
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, **Unit 4:** 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.

Textbooks

- *Steels: Processing, Structure, and Performance, George Krauss; ASM International*

Reference Book(s):

- *Steels: Microstructure and Properties HKDH Bhadeshia and Sir R. Honeycomb; Butterworth-Heinmann, Elsevier Publications*

Course Name: Military Materials
Course Code: MM 619

Course Outcomes (CO):	
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.

	Syllabus Details
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.
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: Armour piercing fin stabilised discarding Sabot, Tungsten heavy alloys as long rod penetrator, Recent development
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 the toughness for missile applications.

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

Textbooks

- *Alistair Doig, Military metallurgy, Maney publishing, 2002*

Reference Book(s):

- *Physical Metallurgy Principles, Robert E Reed Hill, Cengage Learning, Inc publications, 1992*
- *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, 2010.*
- *Paul J Hazell, Armour Materials Theory and Design, CRC Press, 20*

Course Name: Introduction to Corrosion
Course Code: MM 620

Course Outcomes (CO):	
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

	Syllabus Details
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.

Textbooks

- *Mars G. Fontana, Corrosion Engineering, 3rd Ed., McGraw-Hill, Singapore, 1987*

Reference Book(s):

- *H.H. Uhlig and R.W. Revie, Corrosion and its control, 3rd Ed., John Wiley, Singapore, 1991*

<u>Course Name: Welding Science and Technology</u>
<u>Course Code: MM 621</u>

Course Outcomes (CO):	
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

	Syllabus Details
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.
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.
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
Unit IV	Application of above principles to welding of carbon and alloy steels, cast irons, stainless steels, aluminum and titanium alloys. Weld decay, problems associated with welding of metals and alloys. Stabilized alloy
Unit V	Pre and post welding Heat treatment processes, Failure analysis

Textbooks

- *K. Easterling, Introduction to Physical Metallurgy of Welding, Butterworths Pub., 1983.*

Reference Book(s):

- *Sindo Kou, Welding Metallurgy, John Wiley & Sons, New York, 1987.*
- *S.A. David (Ed.), Advances in Welding Science and Technology, American Society for Metals, Ohio, 1986.*

Course Name: High Temperature Corrosion
Course Code: MM 622

Course Outcomes (CO):	
CO-1:	Brief introduction to free energy, partial pressure and related diagrams
CO-2:	Analysis of thermodynamics of high temperature gases with metals
CO-3:	Conception of effects of defect interaction kinetics
CO-4:	Cognizance of corrosion characteristics affecting metals
CO-5:	Understand different applications of high temperature corrosion
CO-6:	Measurement of degradation of materials in high temperature applications
CO-7:	Understanding high temperature corrosion testing

	Syllabus Details
Unit I	Free energy, Partial pressure, Ellingham diagram
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	Theory of point defects in corrosion products, 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	Corrosion product evaporation, analyses of kinetic data; alloy oxidation-kinetics, mechanisms, morphology, hot corrosion of metals and alloys-mechanisms and examples.
Unit V	High temperature corrosion in various applications
Unit VI	Measurements of High – Temperature Degradation, High Temperature Corrosion & Degradation Processes.
Unit VII	High Temperature Corrosion Testing

Textbooks

- *Per Kofstad, High Temperature Corrosion, Elsevier Applied Science, 1988.*
- *U.R. Evans, Corrosion and Oxidation of Metals, Arnold Publ., London, 1981.*

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: Corrosion Mitigation
Course Code: MM 623

Course Outcomes (CO):	
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

	Syllabus Details
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

Textbooks

- *Corrosion: Environment and Industries, Metals Handbook, Vol. 13c, Park Ohio, 1984, 10th Ed., ASM Metals, Ohio, 1987.*
- *N.D. Tomashov, Theory of Corrosion and Protection of Metals, Macmillan, 1967.*
- *M.G. Fontana, Corrosion Engineering, 3rd Ed., McGraw-Hill, 1985. 4. H.H. Uhlig, Corrosion & Corrosion Control, Wiley, 1985.*

Reference Book(s):

- *R. Lambourne and T.A. Strivens, Paint and Surface Coatings, Ellis Horwood D, Chichster, 1987.*
- *C.G. Munger, Corrosion Prevention by Protective Coatings, NACE Pub., Houston, 1984.*
- *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 Name: Advanced Coatings
Course Code: MM 624

Course Outcomes (CO):	
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

	Syllabus Details
Unit I	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

Textbooks

- *R. Lambourne and T.A. Strivens, Paint and Surface Coatings, Ellis Horwood D, Chichster, 1987.*
- *2. C.G. Munger, Corrosion Prevention by Protective Coatings, NACE Pub., Houston, 1984.*

Reference Book(s):

- *3. Surface Finishing, Cleaning & Coatings, ASM Handbook, Vol. 5, 1994.*
- *4. J. Biesiek and J. Weber Portcullis, Electrolytic and Chemical Conversion Coatings, Red Hill Press, 1976.*
- *5. F.A. Lowenheim, Electroplating: Fundamentals of Surface Finishing, McGraw-Hill, New York, 1978.*

Course Name: Surface Science and Engineering
Course Code: MM 625

Course Outcomes (CO):	
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

	Syllabus Details
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.

Textbooks

- *M. Prutton, Surface Physics, 2nd Ed., Clarendon Press, Oxford, 1983.*
- *A.W. Adamson, Physical Chemistry of Surfaces, 3rd Ed., Wiley, 1976.*

Reference Book(s):

- *K.G. Budinski, Surface Engineering for Wear Resistance, Prentice-Hall, 1988.*
- *K.H. ZumGahr, Microstructure and Wear of Materials, Elsevier, 1987.*

Course Name: Reliability Engineering
Course Code: MM 626

Course Outcomes (CO):	
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

	Syllabus Details
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.

Textbooks

- *G. Haribaskaran, Probability, Queuing Theory & Reliability Engineering, Laxmi publications, Second Edition.*
- *D. H. Besterfield, Glen H. Besterfield and M. Besterfield-Sacre, Total Quality Management, Pearson Publications, Third Edition*

Reference Book(s):

- *E. Walpole, H. Myers and L. Myers, Probability and Statistics for engineering and Scientists, Pearson Publications, Eighth Edition.*
- *BrendBretsche, Reliability in Automotive and Mechanical Engineering, Springer Publications.*
- *G. Pahl, W. Bietz, J. Feldhusen and K. H. Grote, Engineering Design a Systematic approach, Springer Publications, Third Edition.*
- *V. Sankar, System Reliability Concepts, Himalaya Publishing House, 2015.*
- *Roy Billinton and Ronald N. Allan, Reliability Evaluation of Engineering Systems, Reprinted in India B. S. Publications, 2007.*
  E. Balagurusamy, Reliability Engineering, Tata McGraw Hill, 200

School of Energy & Envirnment

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 the opposite to 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:

(iii) Sponsored candidates from the Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments

(iv) 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. Every course will have three continuous evaluation examinations and a final semester examination. 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 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.

Credit Structure

Semester1

Sr. No.	Course Code	Course	Contact Hours/week			Credits
			L	T	P	
1	SE 601	Fundamentals of Energy Studies	3	1	0	4
2	SE 602	Bioenergy Systems	3	1	0	4
3	SE 603	Hydrogen Energy	3	1	0	4
4	SE 604	Waste to Energy	3	1	0	4
5	SE 605	Solar Energy Systems	3	1	0	4
6	SE 606	Renewable Energy and Environmental Sustainability	3	1	0	4
7	PGC 601	Research Methodology and IPR	2	0	0	2
		Total	**20**	**6**	**0**	**26**

Semester II

Sr. No.	Course Code	Course	Contact Hours/Week			Credits
			L	T	P	
1	SE 607	Wind and Hydro Energy Systems	3	1	0	4
2	SE 608	Geothermal and Ocean Energy	3	1	0	4
3		Departmental Elective I	3	1	0	4
4		Departmental Elective II	3	1	0	4
5		Elective – III	3	1	0	4

6		Elective - IV	3	1	0	4
7	PGC 602	Communication Skills & Personality Development	2	0	0	2
		Total	20	6	0	26

Semester III

Sl. No.	Course Code	Course	Contact Hours/Week			Credits
			L	T	P	
1	SE 651	M.Tech. Dissertation Phase - I	0	0	28	14
		Total			**28**	**14**

Semester IV

Sl. No.	Course Code	Course	Contact Hours /week			Credits
			L	T	P	
1	SE 652	M.Tech. Dissertation Phase - II	0	0	28	14
		Total			**28**	**14**

Course Code	Course Name	L – T – P	**Credits**
SE 601	**Fundamentals of Energy Studies**	3-1-0	**4**

Course Objectives:

- To impart knowledge of the domain of Energy Science and Technology and various forms of energies
- To inform the student about the Energy related organizations and Government Bodies
- To enable the student to identify technical details for power plant economics
- To illustrate and classify waste heat recovery systems
- To analyze and understand various biofuels and their characteristics

Course Contents

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- Comparison of Fuels such as Wood, Charcoal, Coal, Kerosene, Diesel, Petrol, Furnace Oil, LPG, Biogas and Electricity on calorific value and cost basis - Efficiencies of various Energy production.

Unit II

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

Unit III

Load Duration Curve –Load factor – Capacity factor – Reserve factor – Demand Factor – Diversity factor –Plant use factor – Location of power plants – Power Plant Economics – Indian Energy Scenario – problems – solutions -power plant sizing based on screening curve method.

Unit IV

Decentralized power generation – concept –Cogeneration – definition – need - application - advantages- classification - saving potentials -Waste heat recovery - Classification- advantages and applications - commercially viable waste heat recovery devices - saving potential – Combined Heat and Power

Unit V

Biofuels – Edible –Petro crops – Analysis of Indian non-edible oil sources – Example of biodiesel crop – Jatropha curcas – Tree description – Jatropha curcas for rural development – environmental protection – Bioethanol – production from conventional as well as unconventional sources. - Biodiesel – Technology for production of biodiesel - Transesterification – Process – Usage of Methanol – Glycerine – Storage and Characterization of biodiesel – Biodiesel engine development – modification – Environmental and health effects of biodiesel – R&D in biodiesel – disposal of cake – value addition of by-products.

Course Outcomes

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

CO1: Understand the domain of Energy Science and Technology and various forms of energies

CO2: Know about the Energy related organizations and Government Bodies

CO3: Identify technical details for power plant economics

CO4: Illustrate and classify waste heat recovery systems

CO5: Analyse and understand various biofuels and their characteristics

Text Books

1. Rai, G.D., "Non-Conventional Sources of Energy", Khanna Publishers, Delhi 1995.

2. Rao S, Parulekar B.B, “Energy Technology – Non conventional, Renewable and

Conventional" Khanna Publishers, 1999.

. H.G. Stoll, Least Cost Electrical Utility / Planning, John Wiley & Sons, 1989.

Reference Books

1. Koushika M.D., "Solar Energy Principles and Applications", IBT publications, 1988.

2. Mital K.M, "Biogas systems: Priciples and Applications", New Age International Publishers (P) Ltd., 1996

3. Venkata Ramana P and Srinivas S.N., "Biomass Energy Systems", TERI, 1996.

Course Code	Course Name	L – T – P	**Credits**
SE 602	**Bioenergy Systems**	3-1-0	**4**

Course Objectives:

- To impart knowledge of the current Bio energy status of the world and India
- To interpret the technical details of Biomass energy systems
- To perform classification of different types of stoves and burners
- To Analyze the Biogas plants and technical details of biogas production
- To identify and explain different Biomass gasifier systems

Course Contents

Unit I

Bio Energy Resources, World Bio Energy Potential, India's Bio-Energy Potential, Current Technology and Research Status.

Unit II

Direct Combustion, Technology of Biomass gasification, Pyrolysis and Liquefaction, Bio-Chemical Conversion: anaerobic digestion, alcohol production from biomass, Chemical conversion process: hydrolysis and hydrogenation

Unit III

Traditional Stoves, Energy Efficient Cooking and Space Heating Stoves, Metal Stoves Improved Gasifier Stoves, Current Research Status, Pollution due to smoke emissions.

Unit IV

The technology of Bio-gas production, Biogas Plants, Digester types, Digester design, Chemical kinetics and mathematical modeling of biomethanation process, Dung, Vegetable Waste and Night Soil and Municipal Waste based Bio-gas plants, Biogas as fuel for transportation, Lighting, Running Dual Fuel Engines, Electricity generation, Biogas

Bottling Plant Technology, Application of Biogas slurry in agriculture, Design of Biogas for cold climates **Unit V** History, Principle, and Design of Biomass Gasifiers, updraft gasifiers, down draft gasifiers, zero carbon biomass gasification plants, Gasification of plastic-rich waste, applications for cooking, electricity generation, Gasifier Engines, Operation of spark ignition and compression ignition engine with wood gas, methanol, ethanol and biogas, Biomass integrated gasification/combined cycles systems. Environmental Policy Issues of Bio-Energy systems.
Course Outcomes
After completing this course, the students will be able to: **CO1:** Understand the current Bio energy status of the world and India **CO2:** Interpret the technical details of Biomass energy systems **CO3:** Perform classification of different types of stoves and burners **CO4:** Analyse the Biogas plants and technical details of biogas production **CO5:** Identify and explain different Biomass gasifier systems
Text Books
1. B Sorensen, Renewable Energy,2nd Ed, Academic press, New York, 2000 2. G Boyle (Ed), Renewable energy: Power for a sustainable future, Oxford, OUP, 1996
Reference Books
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

Course Code	Course Name	L – T – P	**Credits**
SE 603	**Hydrogen Energy**	3-1-0	**4**

Course Objectives:

- To understand the basic concepts of hydrogen as a fuel
- To identify different types of fuel and their characteristics
- To analyze and understand the technical details of coal and its use as an energy source
- To illustrate the classification of gaseous fuels
- To analyze and understand the combustion process and emission from different fuels

Course Contents

Unit I

Hydrogen properties, uses, interest in hydrogen as fuel, methods of production, storage, transportation, distribution, hydrogen economy **.**

Emissions from fuel combustion systems: Pollutants and their generation, allowed emissions, strategies for emission reduction, Euro and BIS norms for emission, recent protocols

Unit II

Basics of fuels: Modern concepts of fuel, Solid, liquid, and gaseous fuels, composition, a basic understanding of various properties of solid fuels - heating value, ultimate analysis, proximate analysis, ash deformation points; liquid fuels - heating value, density, specific gravity, viscosity, flash point, ignition point (self, forced), pour point, ash composition, and gaseous fuels.

Unit III

Coal as a source of energy: Coal reserves – World and India, Coal liquefaction process, various types of coal and their properties, Origin of coal, composition of coal, analysis and properties of coal, Action of heat on coal, caking and coking properties of coal; Processing of coal: Coal preparations, briquetting, carbonization, gasification and liquefaction of coal, Coal derived chemicals.

Unit IV

Natural gas and its derivatives: Classification of gaseous fuels – natural gas and synthetic gases, Natural gas reserves - World and India, properties of natural gas – heating value, composition, and density

Unit V

Principles of combustion: Chemistry and Stoichiometric calculation, thermodynamic analysis, and concept of adiabatic flame temperature; Combustion appliances for solid, liquid, and gaseous fuels: working, design principles and performance analysis

Course Outcomes
After completing this course, the students will be able to: **CO1:** Understand the basic concepts of hydrogen as a fuel **CO2:** Identify different types of fuel and their characteristics **CO3:** Analyse and understand the technical details of coal and its use as an energy source **CO4:** Illustrate the classification of gaseous fuels **CO5:** Analyse and understand the combustion process and emission from different fuels
Reference Books
1. Fuels & Combustion by Sharma S.P. & Chander Mohan, Tata McGraw Hill Publishing Co. Ltd. 2. Fuels & Combustion by Sarkar Samir, Orient Longman. 3. Fuels and Petroleum Processing by Sharma, B. K, Goel publishing.

Course Code	Course Name	L – T – P	**Credits**
SE 604	**Waste to Energy**	3-1-0	**4**

Course Objectives:

- To understand the basic concepts of solid waste and disposal systems
- To classify different techniques of waste treatment
- To analyze the process of energy generation from different waste
- To characterize the rural biomass usage and products/by-products of the process
- To illustrate the various aspects of biomass combustion and the processes involved

Course Contents

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 Landfill - Movement and control of landfill leachate &gases; Environmental monitoring system for landfill gases. - Gas Recovery – Applications

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.

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 bio-digestion - Activated sludge process. Methods of treatment and recovery from the in industrial wastewater – Case Studies in sugar, distillery, dairy, pulp and paper mill, fertilizer, tanning, steel industry, textile, petroleum refining, chemical and power plant.

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-Briequtting machine

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

Course Outcomes

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

CO1: Understand the basic concepts of solid waste and disposal systems

CO2: Classify different techniques of waste treatment

CO3: Analyse the process of energy generation from different waste

CO4: Characterize the rural biomass usage and products/by-products of the process

CO5: Illustrate the various aspects of biomass combustion and the processes involved

Text Books

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
Reference Books
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.

Course Code	Course Name	L – T – P	**Credits**
SE 605	**Solar Energy Systems**	3-1-0	**4**

Course Objectives:

- To understand the technical details of solar radiation
- To analyze different ways to utilize the solar energy
- To examine the ways solar energy proves beneficial in providing thermal comfort in buildings
- To identify the technical details of solar cells and their performance parameters
- To explain the applicability of solar photovoltaic systems and their operation

Course Contents

Unit I

Solar angles, day length, angle of incidence on tilted surface; Sunpath diagrams; Shadow determination; Extraterrestrial characteristics; Effect of earth atmosphere; Measurement & estimation on horizontal and tilted surfaces; Analysis of Indian solar radiation data and applications. Flat-plate Collectors - Effective energy losses; Thermal analysis; Heat capacity effect; Testing methods; Evacuated tubular collectors; Air flat-plate Collectors: types; Thermal analysis; Thermal drying. Selective Surfaces -Ideal coating characteristics; Types and applications; Anti-reflective coating; Preparation and characterization

Unit II

Concentrating Collector Designs - Classification, Tracking systems; Compound parabolic concentrators; Parabolic trough concentrators; Concentrators with point focus; Heliostats; Comparison of various designs: Central receiver systems, parabolic trough systems; Solar power plant; Solar furnaces - Vapour absorption refrigeration cycle; Water, ammonia & lithium bromide-water absorption refrigeration systems; Solar operated refrigeration systems; Solar desiccant cooling. -Solar Thermal Energy Storage - Sensible storage; Latent heat storage; Thermo-chemical storage. Solar still; Solar cooker: Solar pond.

Unit III

Solar Passive Building - Thermal comfort; Criteria and various parameters;

Calculation of solar radiation on buildings; building orientation; Introduction to design of shading devices; Overhangs; Factors that effects energy use in buildings; Ventilation and its significance; Air- conditioning systems; Passive Cooling And Heating Concepts – Passive 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; Shading, paints and cavity walls. **Unit IV** Solar Cell Physics –P-N junction: homo and hetro junctions, Metal-semiconductor interface; Dark and illumination characteristics; Figure of merits of solar cell; Efficiency limits; Variation of efficiency with band-gap and temperature; Efficiency measurements; High efficiency cells, Tandem structure. **Unit V** SPV Applications - Centralized and decentralized SPV systems; Stand alone, hybrid and, grid connected system, System installation, operation and maintenances; Field experience; PV market analysis and economics of SPV systems – Government Schemes and Polices
Course Outcomes
After completing this course, the students will be able to: **CO1:** Understand the technical details of solar radiation **CO2:** Analyse different ways to utilize the solar energy **CO3:** Examine the ways solar energy proves beneficial in providing thermal comfort in buildings **CO4:** Identify the technical details of solar cells and their performance parameters **CO5:** Explain the applicability of solar photovoltaic systems and their operation
Text Books
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
Reference Books
1. D Y Goswami, Frank Kreith and J F Kreider,Principles of Solar Engineering, Taylor& Francis, 1998 2. Tiwari G.N., Suneja S., Solar Thermal Engineering System, Narosa Publishing House, New Delhi, 1997.

Course Code	Course Name	L – T – P	**Credits**
SE 606	**Renewable Energy and Environmental Sustainability**	3-1-0	**4**

Course Objectives:

- Understand the importance of environment in energy generation and consumption
- Understand the social and economic impacts of actions in energy & environment
- Analyse status and possibilities in rural electricity generation & utilization
- Review the various energy & environment related policies from Government
- Explain the applications of renewable energy technologies in rural areas

Course Contents

Unit I

Environmental sustainability, Traditional and modern energy use, Methods of accounting for the role of traditional energy in the overall energy system. Energy consumption patterns in rural areas. Trends of rural energy consumption, need and development of rural energy databases (REDB); methodologies for building REDB. Case studies of REDB

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. The debate of black carbon from biomass burning. The energy ladder for cooking. Gender issues in biomass collection and processing.

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

Unit IV

Review and critique of various programs of government: National Program for Biogas Development (NPBD), National Program for Improved Cookstoves (NPIC), Village Energy Security Plan (VESP), Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) etc.

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

Course Outcomes

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

CO1: Understand the importance of environment in energy generation and consumption

CO2: Understand the social and economic impacts of actions in energy & environment **CO3:** Analyse status and possibilities in rural electricity generation & utilization **CO4:** Review the various energy & environment related policies from the Government **CO5:** Explain the applications of renewable energy technologies in rural areas
Text Books
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
Reference Books
1. Chambers, Ann, Distributed Generation: A Non-technical guide, 4th Ed., Penn well, Oklahoma, 2001 2. 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, Macmilan, New Delhi, 2003

Course Code	Course Name	L – T – P	**Credits**
SE 607	**Wind and Hydro Energy Systems**	3-1-0	**4**

Course Objectives:

- To understand the technical details of wind energy conversion physics
- To analyze the design and performance characteristics of wind turbines
- To examine different hydropower systems
- To illustrate the possibilities in hydropower generation and utilization
- To explain the ocean thermal, geothermal, and thermo-electric energy systems

Course Contents

Unit I

Wind Energy Conversion - Wind energy conversion principles; General introduction; Types and classification of WECS; Power, torque and speed characteristics. – Site Selection Criteria– Advantages – Limitations – Wind Rose Diagram – Indian Wind Energy Data – Organizations like NIWE etc., Wind Energy Conversion System - Design – Aerodynamic design principles; Aerodynamic theories; Axial momentum, blade element and combine theory; Rotor characteristics; Maximum power coefficient; Prandlt’s tip loss correction.

Unit II

Design of Wind Turbine - Wind turbine design considerations; Methodology; Theoretical simulation of wind turbine characteristics; Test methods. Wind Energy Application - Wind pumps: Performance analysis, design concept and testing; Principle of WEG; Standalone, grid-connected and hybrid applications of WECS; Economics of wind energy utilization; Wind energy in India; Case studies.

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.

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

Unit V

OTEC- Tidal Energy- Geothermal- MHD - Thermionic- Thermoelectric energy conversion system- Fuel Cells – Batteries – Micro Alge – Biodiesel from Alge.

Course Outcomes

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

CO1: To understand the technical details of wind energy conversion physics

CO2: To analyse the design and performance characteristics of wind turbines

CO3: To examine different hydropower systems

CO4: To illustrate the possibilities in hydropower generation and utilization

CO5: To explain the ocean thermal, geothermal, and thermo-electric energy systems

Text Books

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)

Reference Books
1. Paul Gipe , Karen Perez, Wind Energy Basics: A Guide to Small and Micro Wind Systems, Chelsea Green Publishing Company; (1999) 2. J. F. Manwell, J. G. McGowan, A. L. Rogers, Wind Energy Explained , John Wiley & Sons; 1st edition (2002)

Course Code	Course Name	L – T – P	**Credits**
SE 608	**Geothermal and Ocean Energy**	3-1-0	**4**

Course Objectives:

- To impart knowledge on Geothermal energy resources, overall potential, development stages, and various devices used to harness Geothermal Energy.
- To impart knowledge on various forms of Ocean Energy, overall potential, development stages, and various devices used to harness Ocean Energy.
- To understand the functioning of various technical devices that operate on Geothermal and Ocean energy, and solve problems on operation and performance.

Course Contents

Unit I

Introduction of Geothermal Energy, Geothermal Resources; definition and classification, Hydrothermal System, Hot dry rock system, Geopressured reservoirs, Magma Energy, Dry rock and hot aquifer analysis. utilisation of geothermal resources, Direct utilization; Swimming bathing and balneology, space conditioning, district heating.

Unit II

Geothermal heat pump, basic concept of heat pump, air conditioner, heating and cooling mode in heat pump, Heat pump with geothermal resources; typical GHP loop configuration.

Unit III

Basics of Ocean Energy, Oceanography and Meteorology, weather, and climate, Description of World's Oceans, currents, salinity, ocean floor characteristics, Ocean Thermodynamics, Ocean circulation, and currents, Heat-induced tropical circulations; Other forms of Ocean Energy- Wave energy and Tidal Energy- importance, applications, and energy potential.

Unit IV

Ocean Thermal; Introduction, OTEC history and technology progress, working principle, open, closed and hybrid cycle, resources, and site requirement; Tidal energy devices stream generators, barrages, and lagoons. Wave energy devices- Wave profile devices, Oscillating wave columns, wave energy converters.

Course Outcomes
After completing this course, the students will be able to: **CO1:** Learn about basics of geothermal energy, its potential, various ways to utilize the geothermal energy. **CO2:** Understand about geothermal heat pump and solve the problems on operation and performance of geothermal heat pump. **CO3:** Learn about basics of ocean energy, its potential and types, wave energy, tidal energy, ocean thermal energy, their significance and various ways to utilize the ocean energy. **CO4:** Understand about Ocean thermal energy, devices and their configuration to extract Ocean thermal energy, energy from salinity gradient, and wave and tidal energy. Solve problems on operation and performance of ocean energy devices.
Text Books
6. Fundamentals and Applications of Renewable Energy, 1st Edition, Mehmet Kanoğlu, Yunus A. Çengel, John M. Cimbala, McGraw Hill, New York, 2020. 7. Geothermal Energy: From Theoretical Models to Exploration and Development, Ingrid Stober, Kurt Bucher, Springer Cham, Switzerland 2021. 8. Fundamentals of Ocean Renewable Energy, Simon P. Neill, M Hashemi, Academic Press, US 2018.
Reference Books
6. The Atmosphere and Ocean: A Physical Introduction (Advancing 2012 Weather and Climate Science), N.C. Wells, Wiley Blackwell, US 2011. 7. Elements of Physical Oceanography, H.J. McLellan, Pergamon Press 1965. 8. Principles of Ocean Physics, J.R. Apel, Academic Press, US 1987.

Course Code	Course Name	L – T – P	**Credits**
SE 609	**Fuel and Combustion Technology**	3-1-0	**4**

Course Objectives:

- To understand the characterization of different types of fuels
- To perform classification of petroleum fuel, its products, and gaseous fuels
- To understand and apply the basic principles in combustion and exhaust analysis
- To illustrate the design concept in burner and associated modifications
- To identify various types of furnaces used in energy industries and their performance

Course Contents

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.

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.

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 (O2, CO2, CO, NOx, SOx).

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

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.

Course Outcomes

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

CO1: To understand the characterization of different types of fuels
CO2: To perform classification of petroleum fuel, its products, and gaseous fuels
CO3: To understand and apply the basic principles in combustion and exhaust analysis
CO4: To illustrate the design concept in burner and associated modifications
CO5: To identify various types of furnaces used in energy industries and their performance

Text Books

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 Corpn.,1988

Reference Books

1. Gupta O.P, Elements of Fuels, Furnaces & Refractories, 3rd edition, Khanna Publishers, 1996.

2. Samir Sarkar, Fuels & Combustion, 2nd Edition, Orient Longman, 1990

Course Code	Course Name	L – T – P	**Credits**
SE 610	**Integrated Energy Systems**	3-1-0	**4**

Course Objectives:

- To understand the need for storage and utilization principles of various energy forms
- To interpret the technical details of magnetic and electrical energy systems
- To analyze the different energy storage systems and their applications

Course Contents

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.

Unit II

Magnetic and Electric Energy Storage Systems: Superconducting Magnet Energy Storage (SMES) systems, Capacitor and Batteries, Comparison and application, Supercapacitor: Electrochemical Double Layer Capacitor (EDLC), the principle of working, structure, performance and application, the 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.

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.

Unit IV Some Areas of Application of Energy Storage: Food preservation, Waste heat recovery, Solar energy storage, Greenhouse heating, Power plant applications, Drying and heating for process industries
Course Outcomes
After completing this course, the students will be able to: **CO1:** To Understand the need of storage and utilization principles of various energy forms **CO2:** To Interpret the technical details of magnetic and electrical energy systems **CO3:** To Analyse the different energy storage systems and their applications
Text Books
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
Reference Books
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.

Course Code	Course Name	L – T – P	**Credits**
SE 611	**Rural Electrification Technologies**	3-1-0	**4**
Course Objectives: • Understand the basic concepts of technologies for rural electrification • Interpret the technical details of the electrification process • Classify the different turbine generator and their usage • Illustrate the concepts and current status of biomass-based electricity generation • Identify the technical and economic details of the power grid			

Course Contents

Unit I

Decentralized generation technologies; Costs and choice of technology, Demand and benefits forecasting and program development, Principles of cost-benefit calculations.

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.

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.

Unit IV

Biomass-based generation; DG Evaluation: Cost from past, present, and future, basic DG cost analysis, cost Evaluation, and schedule of demand

Unit V

The power grid; DG-Grid interconnection issues, Mini and Micro Grids – Economics– Environmental Factors – Transmission and Regulations

Course Outcomes

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

CO1: Understand the basic concepts of technologies for rural electrification

CO2: Interpret the technical details of the electrification process

CO3: Classify the different turbine generator and their usage

CO4: Illustrate the concepts and current status of biomass-based electricity generation

CO5: Identify the technical and economic details of power grid.

Text Books

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.

4. T. Gonen: Electric Power Distribution System Engineering, McGraw-Hill 1986.

Reference Books
1. M Mohan: Rural electrification for development: policy analysis and applications. Boulder: Westview Press, 1987 2. G. Saunier: Rural electrification guidebook for Asia and the Pacific, Asian Institute of Technology, 1992.

Course Code	Course Name	L – T – P	**Credits**
SE 612	**Energy Storage and Transport Systems**	3-1-0	**4**

Course Objectives:

- To understand the requirements and different ways of energy storage
- To identify the different technologies and parameters related to energy storage
- To illustrate the design and application areas of energy storage and modern energy solutions

Course Contents

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.

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.

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..

Course Outcomes

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

CO1: Understand the requirements and different ways of energy storage CO2: Identify the different technologies and parameters related to energy storage CO3: Illustrate the design and application areas of energy storage and modern energy solutions
Text Books
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
Reference Books
1. Electric & Hybrid Vehicles by G. Pistoia, Elsevier B. V. 2. Thermal energy storage: Systems and Applications by Dincer I. and Rosen M. A., Wiley pub.

Course Code	Course Name	L – T – P	**Credits**
SE 613	**Energy Auditing and Management**	3-1-0	**4**

Course Objectives:

- To understand the basics of energy and principles of its conservation and management
- To analyse and understand different technical terms in energy audit
- To classify different furnace types, boilers, and performance parameters
- To illustrate different electric motor types and technical details of their operation
- To understand and interpret various environment concerns and various guidelines

Course Contents

Unit I

Basics of energy & its various forms: Electricity basics – DC and AC currents, 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.

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.

Unit III

Boilers: Types, combustion in boilers, performance evaluation, analysis of losses, feed water treatment, blow down, energy conservation opportunities. Furnaces: Classification, general fuel economy measures in furnaces, excess air, heat distribution, temperature control, draft control, 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: Maximum demand controllers, Automatic power factor controllers, Energy efficient motors, Soft starters with energy saver, Variable speed drives, Energy efficient transformers

Unit V

Energy Conservation Act-2001 and its Features. Global environmental concerns: United Nations Framework Convention on Climate Change (UNFCC), Kyoto Protocol, Conference of Parties (COP), Clean Development Mechanism (CDM), Prototype Carbon Fund (PCF), sustainable development

Course Outcomes

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

CO1: To understand the basics of energy and the principles of its conservation and management

CO2: To analyze and understand different technical terms in an energy audit

CO3: To classify different furnace types, boilers, and performance parameters

CO4: To illustrate different electric motor types and technical details of their operation

CO5: To understand and interpret various environmental concerns and various guidelines

Text Books

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

Reference Books
1. Thuman A and Mehta D Paul, Handbook of Energy Engineering, The Fairmount Press., 1998 2. Kennedy, Turner and Capehart, Guide to Energy Management, The Fairmount Press., 1996

Course Code	Course Name	L – T – P	**Credits**
SE 614	**Energy Modelling and Simulation**	3-1-0	**4**

Course Objectives:

- To develop an understanding on macroeconomics and econometrics of energy, equip student to solve large energy sector input output problems and energy demand forecasting.
- To introduce the concepts of design and simulation of energy systems and solve problems of system-level energy analysis.
- To impart knowledge on optimization of energy systems and solve problems using various optimization techniques.
- To familiarize students with concepts of environmental impact assessment and steps involved in the process.

Course Contents

Unit I

Macroeconomic Concepts, Economics of Energy Sources - Reserves and Cost Estimation, Multiplier Analysis - Energy and Environmental Input / Output Analysis – Energy Aggregation –Econometric.

Unit II

Energy Demand Modelling, - Overview of Econometric Methods. Methodology of Energy Demand Analysis - Methodology for Energy Technology Forecasting -Methodology for Energy Forecasting - Sectoral Energy Demand Forecasting.

Unit III

Introduction to design and simulation, system definition, information flow diagram, techniques of system simulation, Quantitative Analysis: Interpolation, curve fitting, regression analysis, solution to non-linear algebraic equations, successive substitution, Newton-Raphson method, applications to energy systems simulations.

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, Introduction to Linear and Dynamic Programming, application of optimization to energy systems

Unit V

Environmental Impact Assessment (EIA)- Basic concepts, origin, and principles, EIA early stages, Impact prediction, evaluation, mitigation and enhancement, EIA case studies for renewable energy systems

Course Outcomes

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

CO1: Understand the macroeconomic input output energy matrices. Solve problems on sectoral output estimation with changed demand.

CO2: Learn about standard methods of demand forecasting, solve problems on energy demand forecasting using the above methods.

CO3: Learn about various system simulation techniques and apply them to simulate various energy systems and learn to program such methods in Python.

CO4: Understand fundamentals of optimization, learn about optimization techniques and apply them to solve energy system optimization problems.

CO5: Familiarize with concepts of environmental impact assessment, its necessity, and various steps involved.

Text Books

9. M. Munasinghe and P. Meier Energy Policy Analysis and Modeling, Cambridge University Press 1993.
10. W.A. Donnelly, The Econometrics of Energy Demand: A Survey of Applications, New York.1987.
11. C. Balaji, Thermal Systems Design and Optimization, Springer Cham, 2021.

Reference Books

1. Pindyck and Daniel L. Rubinfeld Econometrics Models and Economic Forecasts, 3rd edition MC Graw -Hill, New York 1990.
2. Steven Chapra and Raymond Canale, Numerical methods for engineers (fifth edition), Mc Graw Hill, New York 2005.
3. W. F. Stoecker, Design of Thermal Systems, Mcgraw Hill, New York 1981.
4. J Glasson, R Therivel, A Chadwick, Introduction to Environment Impact Assessment, Fourth Edition, Taylor and Francis, UK, 2012.

Course Code	Course Name	L – T – P	**Credits**
SE 615	**Smart Grid**	3-1-0	**4**

Course Objectives:

- Understand the basic concepts and current status of smart grids in India
- Identify different communication networks and technical details
- Analyze the use of power electronics in smart grid systems
- Illustrate technologies for the improvement of smart grid systems
- Explain the challenges and possibilities in transmission systems

Course Contents

Unit I

Introduction –driving the move towards Smart Grids globally and in India Smart Grid. Overview of how the Indian power market is organized and 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, and Performance management.

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 inoperability 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, 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.

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

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)).

Course Outcomes

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

CO1: Understand the basic concepts and current status of smart grids in India

CO2: Identify different communication network and technical details

Co3: Analyse the use of power electronics in smart grid systems

CO4: Illustrate technologies for improvement of smart grid systems

CO5: Explain the challenges and possibilities in transmission systems

Text Books

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

Reference Books

1. Technology enabling the transformation of India's power distribution

http://www.infosys.com/newsroom/features/power-sector-report.pdf

2. Gridwise Alliance website http://www.gridwise.org/

Course Code	Course Name	L – T – P	**Credits**
SE 628	**Battery and Fuel Cell Technology**	3-1-0	**4**

Course Objectives:

- Understand the basic concepts and current status of fuel cell technology
- Identify different parts and thermos-chemistry of fuel cell
- Analyse the chemical kinetics of fuel cell
- Understand the characterization of fuel cell
- Explain the challenges and advances in fuel cell technology

Course Contents

Unit I Fundamentals of Battery, Electrochemistry of battery, Classification of Battery, Construction of battery, Lead Acid Battery, Li-ion Battery etc. Difference between battery and fuel cell.

Unit II

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, Nernst equation: Effect of temperature, pressure and concentration on Nernst potential, Concept of Electrochemical Potential.

Unit III

Components of Fuel cell: Electrolyte, catalyst, bipolar plate/current collector, Activation Polarization-electrochemical kinetics, reaction rate, surface coverage, Activation polarization for charge transfer reaction, Butler-Volmer equation, Tafel equation.

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

Unit V
Comparison of High temperature and low-temperature fuel cells, Different types of fuel cells Hydrogen production and storage, safety issues and Cost issues Advances in solid oxide fuel cells

Course Outcomes

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

CO1: Understand the basic concepts and current status of fuel cell technology **CO2:** Identify different parts and thermos-chemistry of fuel cell **CO3:** Analyse the chemical kinetics of fuel cell **CO4:** Understand the characterization of fuel cell **CO5:** Explain the challenges and advances in fuel cell technology
Text Books
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.
Reference Books
1. Liu, H., Principles of fuel cells, Taylor & Francis, N.Y 2. Electrochemistry of cleaner environments, J OM Bockris , Springer, US

Course Code	Course Name	L – T – P	**Credits**
SE 632	**Energy Efficient Materials**	3-1-0	**4**

Course Objectives:

- Understand the basic concepts of alternative material
- Understand and analyze solar photovoltaic system
- Analyze the fuel cell technology
- Illustrate technologies like thermoelectric and energy harvesting
- Explain the potential of nuclear-based materials

Course Contents

Unit I

Need for Alternative materials, Green Materials, Biomaterials, Natural and synthetic Polymers.

Unit II

Photovoltaic (PV) thin films for solar cells; Organic Solar Cells; dye-sensitized solar cells; Thermo photovoltaic (TPV) devices.

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.

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, Ultracapacitors; Supercapacitors. Thermoelectric, Novel illumination sources for efficient lighting, Energy saving in buildings **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, modeling and theoretical aspects
Course Outcomes
After completing this course, the students will be able to: CO1: Understand the basic concepts of alternative material CO2: Understand and analyze solar photovoltaic system CO3: Analyse the fuel cell technology CO4: Illustrate technologies like thermoelectric and energy harvesting CO5: Explain the potential of nuclear-based materials
Reference Books
1. Materials for Renewable and Sustainable Energy (Springer).

SE-616: **Renewable Energy Laboratory**

Course outcomes

CO-1:	Understand the application of solar energy and utilization
CO-2:	Understand the application of wind energy and utilization
CO-3:	Analyse the biomass systems
CO-4:	Understand the formation of biogas system
CO-5:	Explain the challenges and advances in Renewable Energy

Laboratory I:

1. Study on greenhouse effect on solar flat plate collector
2. Estimation of instantaneous efficiency of a solar liquid flat plate collector
3. Study on solar flat plate collector in series and parallel combination
4. Estimation of efficiency of solar air heaters

5. Estimation of efficiency of solar still
6. Performance evaluation of concentrating solar collector
7. Performance evaluation of solar cooker
8. Estimation of efficiency of solar photovoltaic panels
9. Effect of Shadow & tilt angle on solar photo voltaic panel
10. Study on solar photo voltaic panel in series and parallel combination
11. Study on charging characteristics of a lead acid battery using solar photo voltaic panel.
12. Performance Evaluation of Wind Electric Generator
13. Performance Evaluation of Wind Water Pumping System
14. Study on Grid Integration of Wind Electric Generator

Laboratory II:

1. Proximate analysis of solid wastes
2. Calorific value of solid wastes
3. Combustion characteristics of solid wastes
4. Study of Composting of solid wastes
5. Estimation of energy recovery potential of solid wastes
6. Study of refuse derived fuel (RDF)
7. Estimation of BOD, DO level in effluent
8. Estimation of COD level in effluent
9. Evaluation of Fixed Dome biogas plant
10. Evaluation of Floating Drum biogas plant
11. Performance analysis of gasifier
12. Performance analysis various wood stoves
13. Estimation of Calorific Value of Gaseous fuels
14. Characteristics of Fuel Cell
15. Analysis of Non-Edible oil as alternate energy source

M.Sc. Food Technology

DEPARTMENT OF APPLIED CHEMISTRY

(In association with DFRL, Mysore)

PROGRAMME STRUCTURE

Semester I					
S. No	**Course Code**	**Course**	**L**	**T/P**	**Credit**
1	ACFT 501	Food Chemistry	3	1	4
2	ACFT 502	Food Microbiology	3	1	4
3	ACFT 503	Food and Nutrition	3	1	4
4	ACFT 504	Principles of food processing and preservation	3	1	4
5	RM 501	Research Methodology	3	1	4
Semester II					
1	ACFT 505	Food Analysis & Sensory Evaluation	3	1	4
2	ACFT 506	Technology of Fermented Foods	3	1	4
3	ACFT 507	Food Standards and Safety Management	3	1	4
4	ACFT 508	Technology of Milk & Dairy Products	3	1	4
5	On Job Training (OJT)/Internship (at DFRL) (120 hours)		3	1	4
Semester III					
1	ACFT 509	Fundamentals of Food Engineering	3	1	4
2	ACFT 510	Technology of Fruits, Vegetables and Plantation Crops	3	1	4
3	ACFT 511	Technology of Cereals, Pulses and Oil Seeds	3	1	4
4	ACFT 512	Technology of Meat, Poultry & Fish Processing	3	1	4
5	ACFT 513	Food Packaging Technology	3	1	4
6	RP 541	Minor Project/Project I			2
5	Elective I		3	1	4
Semester IV					
1	RP 542	Major Project/Project II			16
Credits		**Total**			**82**

(Semester I & II will be conducted at DIAT, Pune and semester III & IV will be conducted at DFRL Mysore)

Elective I

S. No.	Course Code	Course
1	ACFT 515	Advanced Food Technology
2	-	Online courses from NPTEL, MOOC
3	-	Open elective from other dept

SEMISTER I

Course Code	Course Name	L – T – P	**Credits**
ACFT 501	**FOOD CHEMISTRY**	**3-0-1**	**4**

Course Objectives:

- To develop understanding about chemical/biochemical reactions that influence food quality with emphasis on food processing industrial applications
- Teach the properties of different food components and how interactions among these components modulate the specific quality attributes of food systems.
- Acquaint the students with the principles that underlay the biochemical/enzymatic techniques used in food proximate and quality/safety analysis.

Course Contents

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.

Unit-7. Fundamentals of Nanotechnology: Basic concepts and applications of nanotechnology in food technology

Practical

1. Principles and working of common instruments.
2. Analysis of water with respect to pH, TDS/TSS, hardness, chlorine, etc.
3. Estimation of moisture and ash
4. Estimation of proteins by various methods

5. Estimation of reducing and non-reducing sugars, starch
6. Estimation of crude and dietary fibres
7. Estimation of minerals and vitamins
8. Analysis of lipids-saponification value, acid value and iodine value.

Course Outcomes

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

CO1: Demonstrate and apply knowledge of the core competencies in food chemistry and analysis.

CO2: Understand the chemistry involved in the properties and reactions of various foods and its components.

CO3: Understand and effectively apply the principles behind analytical techniques associated with food

Text Books

1. Fennema, O.R.2007. Food Chemistry. Marcel Dekker, CRC Press, New York.

References Books

1. Meyer, L.H. 2002. Food Chemistry. CBS publishers and Distributors, New Delhi.
2. Potter, N.N. and Hotchkiss, J.H. (2006), Food Sciences, Fifth edition, CBS publishers and Distributors, New Delhi.
3. Belitz, H.D., Grosch, Werner, Schieberle, Peter 2009. Food Chemistry. Springer Verlag.
4. Salunkhe, O.K. and Kadam, S.S. Eds. 1999. Handbook of World Legumes: Nutritional Chemistry, Processing Technology and.Utilization. Volume I to III. CRC Press, Florida.
5. Salunkhe, D.K. Chavan, J.K., Adsule, R.N. Kadam, S.S. 1992. World Oilseeds: Chemistry, Technology and Utilization, Van Nostrand Reinhold, New York.

Course Code	Course Name	L – T – P	**Credits**
502	**FOOD MICROBIOLOGY**	**3-0-1**	**4**

Course Objectives:

- In-depth knowledge to students on different aspects of microbial growth and associated spoilage in foods.
- Become conversant in basic methods in microbiology and applying appropriate methods to identify microorganisms (media-based).
- Demonstrate practical skills in microscopy and their handling techniques and staining procedures.

Course Contents

Unit-1. Introduction to Microbiology: Historical developments, food microbiology and it's scope, structure, growth & nutrition and reproduction of bacteria, yeast, fungi, algae and viruses- A brief account.

Unit-2. Factors affecting the growth of microorganisms in food - Intrinsic and extrinsic parameters that affect microbial growth. Cultivation of microorganisms.

Unit-3. Microbial spoilage of foods: Different types of spoilage and their control for various foods.

Unit-4. Microorganisms and public health - Food poisoning, types and importance food poisoning. Bacterial agents of food borne illness; non-bacterial agents of food borne illness - poisonous algae, fungi and food borne viruses - A brief account.

Unit-5. Physical and chemical factors influencing the destruction of microorganisms including thermal death time, Z, F and D values. Principles of food preservation; control of water activity.

Unit-6. Determination of microorganisms and their products in food: Sampling plan, sample collection, transport and storage, sample preparation for analysis. Microscopic and culture dependent methods.

Unit-7. Food hygiene and sanitation: Contamination during handling and processing and its control; indicator organisms; Rapid methods in detection of microorganisms.

Practical:

1. Principles and working of common instruments including microscopy.
2. Preparation of nutrient media, sterilization and inoculation techniques
3. Staining techniques–Monochrome staining, negative staining, gram staining, acid fast staining, spore staining, capsule staining and motility of bacteria.
4. Pure culture techniques: isolation of pure cultures from spoiled food
5. Growth characteristics: Methods for determination of microbial numbers– direct and plate count; Generation time.
6. Microbiological quality evaluation of processed food products: a) Water; b) Milk and milk products. c) Fruits and vegetables. d) Egg, meat and fish products; e) canned/ retort processed food and other commonly consumed processed and street foods.
7. **Pathogenic microorganisms**: Different methods for isolation of pathogenic bacteria and fungi from contaminated foods.

Course Outcomes
After completing this course, the students will be able to: **CO1:** Gain knowledge about various types of food contamination and spoilage by microorganisms to address food safety problems and solution in global perspectives. **CO2:** Learn basic microbiological techniques to isolate, characterize the microbes morphologically and compare their characteristics and behavior. **CO3:** Evaluate the microbiological quality of foods by qualitative and quantitative microbiological analyses. **CO4:** Apply the principles of food microbiology to evaluate food related cases in daily application
Text Books
1. Bibek Ray (1996) Fundamental Food Microbiology, CRC Press. 2. James M.J. (2000) Modern Food Microbiology, 5th Edition, CBS Publishers. 3. Prescott LM Harley JP and Klein DA (2006). Microbiology (7th edition) McGraw Hill, Newyork.
Reference Books
1. Barnart, G.J. (1997) Basic Food Microbiology, CBS Publishers. 2. Adam M.R. & Moss, M.O. (1995) Food Microbiology, New Age International P. ltd. 3. Waits MJ. 2001. Industrial Microbiology. Blackwell Science. 4. Ward OP. 1989. Fermentation Biotechnology. Prentice Hall. Garbutt J. 1997. Essentials of Food Microbiology. Arnold Heinemann.

Course Code	Course Name	L – T – P	**Credits**
ACFT 503	**FOOD AND NUTRITION**	**3-0-1**	**4**

Course Objectives:

- To gain a thorough knowledge of Food & Nutrition which would equip the student to face the modern day challenges in Food & Nutrition.
- Systematic subject skills & practical skill within various disciplines of food, health, nutrition, therapeutic nutrition and dietery counselling.
- Developing diet planning skills for healthy and diseased individuals in society for better health management and prevention of diseases

Course Contents

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 compounds as a nutraceutical, regulatory issues for nutraceuticals.

Unit-5. Anti-nutritional factors & toxins: Types, chemistry, properties of anti-nutritional factors & toxins (natural toxins, pesticides and antibiotic).

Course Outcomes

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

CO1: Understand the concept of nutritional imbalances and its relationship with chronic diseases prevailing among different age groups.

CO2: The course gives an opportunity to willing students to establish an enterprise of their own in health & food sectors.

CO3: Evaluate the quality of food based on the theoretical knowledge of Food and Nutrition

Text Books

1. Bamji MS, Krishnaswamy K and Brahmam GNV (Eds) (2009). Textbook of Human Nutrition, 3rd edition. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi

Reference Books

1. Salukhe, O. K. And Kadam, S. S. Eds. 1999. Handbook of world Legumes: Nutritional chemistry, Processing Technology and Utilization Volume I to III. CRC Press
2. Brigelius-Flohe, J and Joost H. G. 2006, Nutritional Genomics; Impact on health and Disease. Wiley VCH.
3. Focus on Nutrition Research, Tony P. Starks, Nova Science, 2006

Course Code	Course Name	L – T – P	**Credits**
ACFT 504	**PRINCIPLES OF FOOD PROCESSING AND PRESERVATION**	3-0-1	**4**

Course Objectives:

- To impart knowledge on the causes of food spoilage and methods of processing and preserving food
- To identify & select processing equipment and preservation methods appropriate for specific foods
- To describe the effects of preservation methods on the quality of food

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

Practical

1. Preparation of syrups and brine solutions
2. Determination of TSS, pH, acidity
3. Demonstration of food processing equipment
4. Calculation of dehydration and rehydration ratio
5. Calculation of water activity and moisture content

Course Outcomes
After completing this course, the students will be able to: **CO1:** Recognise and interpret the role of engineering, chemistry, microbiology and other disciplines and their interdependence in processing and preservation of foods **CO2:** Describe and explain basic principles of several food processing and preservation methods including thermal processing, freezing, dehydration, fermentation, high pressure processing and irradiation. **CO2:** Describe and apply the principles of operation, and the key process parameters for microbial safety and quality of food products.
Text Books
1. Potter, N. N. and Hotchkiss, J. H. 1995. Food Science, Springer Science, Fifth Edition
Reference Books
1. Bawa AS, Raju PS, Chauhan OP. 2013. Food Science. New India Publishing Agency, New Delhi, India. 2. Chauhan OP. 2022. Advances in Food Chemistry - Food Components, Processing and Preservation. Springer, Singapore. 3. Chauhan, O.P. 2019. Non-thermal Processing of Foods. CRC Press. USA. 4. Fellows, P. and Ellis H. 1990. Food Processing Technology: Principles and Practice, New York. 5. Jelen, P. 1985. Introduction to Food Processing. Prentice Hall, Reston Virginia, USA.

SEMISTER II

Course Code	Course Name	L – T – P	**Credits**
ACFT 505	**FOOD ANALYSIS & SENSORY EVALUATION**	3-0-1	**4**

Course Objectives:

- Introduction to Sensory Evaluation – The role of sensory evaluation in the food industry, food flavors and taints and off flavors.
- Holistic approaches to understand colour, flavor, texture profiles of food products: Fruits/ vegetables/ confectionary/ baked goods.
- Sensory Test Methods–Steps to conducting a sensory study; Discrimination Tests; Descriptive Analysis Tests; Consumer Tests

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 foe 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 Outcomes
After completing this course, the students will be able to: **CO1:** Acquire knowledge about sensory attributes, facilities for sensory evaluation sensory evaluation methods of food. **CO2:** Gain knowledge about panel members, their selection, types and tasks, sampling procedure for sensory evaluation, application of consumer tests. **CO3:** Learn statistical testing, accuracy and precision of sensory data and correlation between instrumental and sensory measurements**.**
Text Books
1. Ranganna. Analysis of food and vegetables, ICAR, New Delhi
Reference Books **2.** Fennema, O.R.2007. Food Chemistry. Marcel Dekker, CRC Press, New York. **3.** Sensory Evaluation of Food: Principles and Practices; Harry T. Lawless, Hildegarde Heymann, Springer US, 11-Dec-2013.

Course Code	Course Name	L – T – P	**Credits**
ACFT 506	**TECHNOLOGY OF FERMENTED FOODS**	3-0-1	**4**

Course Objectives:

- To understand the principles of food fermentation technology
- To study the types of starters used in food industry, kinetics and mechanism of microbial growth
- To study the production of various fermented food

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. Soya sauce 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. Volarization of Agri food waste: Bioethanol production, biohydrogen production.

Practical

1. Media preparation and sterilization
2. Fermentation of lactic acid at flask level.
3. Fermentation involving lactic acid bacteria.
4. Identification of simple secondary metabolites such as lactic acid bacteriocins.
5. Fermentation of molasses for ethanol production.

Course Outcomes

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

CO1: Gain knowledge about fermentation technologies used in food industry, learn role of microorganisms in fermentation and to gain skills to control of fermentation processes.

CO2: Evaluate factors that contribute in enhancement of cell and product formation during fermentation process.

CO3: Analyse kinetics of cell and product formation in batch, continuous and fed-batch culture

Text Books
1. Prescott & Dunn (1992). Industrial Microbiology, 4th Edition. CBS Publishers, New Delhi.
Reference Books **1.** Ward, O.P. (1989). Fermentation Biotechnology- Principles, Process and Products. Prentice Hall Publishers, New Jersey. **2.** Stansbury, P.F., Whitakar, A and Hall, S.J. (1995). Principles of Fermentation Technology, Pergamen Press, Oxford. **3.** Rehm, H.J., Read, G.B., Puhler, A and Stadler (1999). Biotechnology, Vol. 1-8, VCH Publications. **4.** Crueger and Crueger (2000) Biotechnology – A Text book of Industrial Microbiology. IInd edition. Panima Publishing company **5.** Bains W. 1993. Biotechnology from A to Z. Oxford Univ. Press. **6.** Crueger W &Crueger A. 2000. Biotechnology: A Textbook of Industrial Microbiology. Madison, USA. **7.** Joshi VK & Pandey A. 2003. Biotechnology Food Fermentation. Vols. I, II.Education Publ. **8.** Knorr D. 2002. Food Biotechnology. Marcel Dekker.

Course Code	Course Name	L – T – P	**Credits**
ACFT 507	**FOOD STANDARDS AND SAFETY MANAGEMENT**	3-0-1	**4**

Course Objectives:

- To develop qualified and competent human resource in the field of the food safety and quality management for regulators, industry, academic/research institutions, certifying and accreditation bodies, food trade, food testing and training
- To delve in depth on various aspects of food safety and quality management i.e. food standards, harmonization with global benchmarks, quality management systems, food analysis, instrumentation, risk analysis /management, traceability and auditing to transform the food ecosystem
- To nurture a positive and disciplined food safety culture among the professionals.

Course Contents
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 Alimentarious 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. CASE STUDIES
Course Outcomes
Upon completion of this course, the student will be able to understand t **CO1:** The principles and methods of Quality Control and Assurance in foods. **CO2:** Understand the principles of HACCP in different food processing, identify hazards and critical control points of different existing production processes **CO3:** Compare different quality systems and assess their usefulness for the food manufacturer and food handler
Text Books
1. Food Safety and standards Act 2006, Rules 2011, Regulations, 2011, 10th Edition, ILBCO India, Indian Law Book Company, 2013
Reference Books
1. The training manual for Food Safety Regulators. Vol.II- Food Safety regulations and food safety management. (2011) Food safety and Standards Authority of India. New Delhi. 2. HACCP: A practical approach, Mortimre, S., and Wallace, C., (2005) 2nd Ed, Aspen. 3. American Society for Quality by Surak, J.G., and Wilson, S. (2007), 2nd Ed., Quality Press 4. FSSAI, FSIS, EU and FAO website for updates

Course Code	Course Name	L – T – P	**Credits**
ACFT 508	**TECHNOLOGY OF MILK AND DAIRY PRODUCTS**	3-0-1	**4**

Course Objectives:

- To acquaint students about the processes involved in the processing of raw milk with constructional details, operation and maintenance of dairy equipments.
- To impart a comprehensive knowledge on chemical and microbiological quality of milk for production of health beneficial foods.
- To impart skills in the application of biological, chemical, biochemical, physical and engineering sciences in processing and preservation of milk and milk products.

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. Cream- Definition, classification, composition, cream separation, sampling, neutralization, sterilization, pasteurization & cooling of cream, evaluation, defects in cream; 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, and technology aspects of softy manufacture.

Unit-5. Cheese: Definition, composition, classification, methods of manufacture, cheddar, Gouda, cottage and processed cheese, evaluation, defects in cheese.

Unit-6. Indigenous milk products - Present status, method of manufacture of milk products.

Unit-7. Milk product processing- cream, butter oil, cheese, cheese spread, condensed milk, evaporated milk, whole and skimmed milk powder, ice cream, khoa, channa, paneer, fermented milk products. Yoghurt, dahishrikhand and similar products. 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 Equipments: 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 curd/lassi.
5. Operation of LTLT & HTST Pasteurization;
6. Spray drying of milk.
7. Preparation of special milks;
8. Cream separation.
9. Standardization of milk from cow and buffalo using Pearson's Method.
10. Preparation and evaluation of table butter, ice cream, cheese and indigenous milk product such as *khoa, chhana, paneer, ghee, rosogolla, gulabjamun, shrikhand, lassi, burfi*
11. Determination of adulterants in milk-by-milk testing kit.

Course Outcomes

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

CO1: Understand the physicochemical properties of milk and various technologies and techniques involved from collection to distribution of milk.

CO2: Understand the technology of fermented milk products and manufacturing techniques, storage, marketing and defects of cheese and butter.

CO3: Understand the technology of frozen milk products technology of evaporated and dried milk technology of condensed milk and their defects and control.

CO4: Understand the technology of dairy by product and their utilization, technology of indigenous milk product and process of manufacturing.

Text Books

1. Walstra P. (Ed.). 2006. *Dairy Science and Technology*. 2nd Ed. Taylor & Francis.

Reference Books

1. Aneja RP, Mathur BN, Chandan RC & Banerjee AK. 2002. *Technology of Indian Milk Products*. Dairy India Publ.

2. Walstra P. 1999. Dairy Technology. Marcel Dekker.
3. Dey S.1994. Outlines of Dairy Technology. Oxford Univ. Press, New Delhi.
4. Rathore NS et al. 2008. Fundamentals of Dairy Technology - Theory & Practices. Himanshu Sharma, H, Pandey H, Singh C. 2009. Dairy Science and Technology and Food and Dairy Engineering. CBS Publishers.
2. Spreer E. 1998. Milk and Dairy Product Technology. Marcel Dekker, New York.

SEMISTER III

Course Code	Course Name	L – T – P	**Credits**
ACFT 509	**FUNDAMENTALS OF FOOD ENGINEERING**	3-0-1	**4**

Course Objectives:

- To acquaint the students about basics of cost-effective design, production, and commercialization of sustainable, safe, nutritious, and high-quality foods
- To understand the concept of development of food systems, machinery, and instrumentation.
- To understand the concept of rheological and thermal properties of foods on measuring the various engineering properties of food products

Course Contents

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, centrifulgal 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

Practicals

- Mechanical drawing
- Refrigeration plant
- Boiler house
- Pilot plant
- Electrical laboratory
- Instrumentation
- Pumps and Flow meters
- Mass and energy balance
- Determination of water activity
- Heat treatment : pasteurization and sterilization
- Thermal Process calculations
- Canning operations
- Dehydration of fruits and vegetables – drying rate curves
- Numerical Problem based on Mass balance
- Size determination
- Mixing, kneading, blending
- Extrusion products
- Filtration and centrifugation
- Freezing curve
- Filtration and centrifugation
- Freezing curve

Course Outcomes

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

CO1: Employ a systematic problem-solving method for addressing engineering questions, including making and testing assumptions, calculate mass and energy balances in the context of food processing equipment **CO2:** Describe the different modes of heat and momentum transfer and explain the effects of each on a food process of interest to the student **CO3:** Select appropriate mathematical models for a given situation and use them to calculate food processing parameters such as sterilization time, heating/cooling rate, or flow rate.
Text Books
1. R.P. Singh and D.R. Heldman, 'Introduction to Food Engineering', Academic Press, INC, London. 2. J.G. Brennan, J.R. Butters, N.D. Cowell and A.E.V. Liley, 'Food Engineering Operations', Elsevier, New York, U.S.A.
Reference Books
1. R.L. Earle, 'Unit Operations in Food Processing', Pergamon Press Oxford, U.K. 2. R.T. Toledo, 'Fundamentals of Food Process Engineering', CBS Publishers, New Delhi, India. 3. J.C. Batty and S.L. Folkman, 'Food Engineering Fundamentals', John Wiley and Sons, New York, U.S.A. 4. J.C. Harper, 'Elements of Food Engineering', AVI, Westport, U.S.A. 5. Harper, J.C. (1976) Elements of Food Engg., AVI Publ. Co., Westport, Connecticut. 6. Brennan, J.Buffers, J.R., Cowell N.D., Lilly, A.E.V. (1976). Food Engg. Operations, 2nd Ed., Elsevier, New York. 7. Lewis, M.J. (1987). Physical Properties of Foods & Foods Processing Systems, Ellis Horwood, England. 8. Fellows, P.J. (2015). Food processing technology. Elsevier India. 9. Berk, Zeri. (2009). Food process engineering and technology. Elsevier India. 10. Smith, P.G. 'Introduction to Food Process Engineering' Springer, 2005. 11. Gopala Rao, Chandra, 'Essential of Food Process Engineering', BS Publications.

Course Code	Course Name	L – T – P	**Credits**
ACFT 510	**TECHNOLOGY OF FRUITS, VEGETABLES & PLANTATION CROPS**	3-0-1	**4**

Course Objectives:

- To impart basic knowledge about the importance and management of tropical and dry land fruits grown in India.
- Understanding the principles of biodiversity and strategies in germplasm conservation of fruit crops.
- To disseminate the knowledge on recent developments and innovations in different science and engineering domains of post-harvest management and processing of fruits, vegetables, spices, and plantation crop products.

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 and 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, phytosanitation, 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

Freezing of fruits and vegetables, methods, freezing injury. Dehydration of fruits and vegetables, dehydration methods, physical and chemical changes during drying. 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, squashes,cordials, carbonated beverages, fruit juice powders. Fermented fruits and vegetables products. Jams, jellies, marmalades, preserves and candied products, role of pectin, theory of jelly formation, strength of pectin. Chutneys, sauces, pickles and tomato products.

Unit 4: Fruits and vegetables by-product and their utilization

By-products of fruits and vegetables industry; peel, pomace, oil, pectin, alcohol, enzyme, etc. and their utilization.

Unit 5: Plantation crops

Importance of plantation crops, chemical composition, processing of tea, coffee, cocoa, chicory. Spices, production, processing.

Practicals:

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, preserves and candies
4. Preparation of pickles and chutneys
5. Preparation of tomato products
6. Canning of fruits and vegetables
7. Examination of canned fruits and vegetables
8. Estimation of caffeine in tea and coffee
9. Estimation of pectin
10. Estimation of browning enzymes, PPO and POD
11. Determination of salt content

Course Outcomes

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

CO1: Understand the fundamental components of production technology of plantation crops like fruits, vegetables and spices.

CO2: To know various processing steps involved in plantation crop processing

CO3: To acquaint with the basics of post harvest management of perishables and durable crops

Text Books

1. Ranganna S. (1986). Handbook of analysis and quality control for fruits and vegetable products. Tata Mc Graw-Hill publishing company limited.

Reference Books

1. Girdharilal., Siddappaa, G.S and Tandon, G.L. (1998). Preservation of fruits & vegetables. ICAR,New Delhi.
2. Thompson, A.K., (2003). Fruits and vegetables; Harvesting, handling and storage. Blackwell Publishing.

3. Srivastava, R.P. and Kumar, S. (2006). Fruits and Vegetables Preservation- Principles and Practices.3rd Ed. International Book Distributing Co
4. Wills, R. B. H. (1996). Postharvest: An Introduction to the Physiology and Handling of fruit and vegetables.

Course Code	Course Name	L – T – P	**Credits**
ACFT 511	**TECHNOLOGY OF CEREALS, PULSES AND OIL SEEDS**	3-0-1	**4**

Course Objectives:

- To acquaint the students with production, consumption trends, structure, composition, quality evaluation, and processing technologies for product development and value addition of various cereals, pulses and oilseeds.
- To develop knowhow of proper handling technologies of cereals, pulses and oil seeds to reduce post harvest losses.
- Innovative bakery product development

General introduction and production and utilization trends; Structure and composition of common cereals, pulses and oilseeds. Postharvest storage of grains.

Unit-1. Wheat. Structure, types and physicochemical characteristics; wheat milling - products and by products; factors affecting quality parameters; physical, chemical and rheological tests on wheat flour; additives used in bakery products; flour improvers and bleaching agents; manufacture of bakery products, pasta products and various processed cereal-based foods. Primary and secondary products from wheat.

Unit-2. Rice. 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. Structure, Classification, chemical properties. Primary and secondary processing products. Application in food and allied industries.

Unit-4. Millets: Structure, Bajra, Jowar and Ragi etc. Types & availability, Post-harvest processing handling and processing of millets and their products.

Unit-5. Bakery: 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; quality consideration and parameters; Staling and losses in baking; machineries used in bakery industry. Chapati making process and qualities, Staling losses in baked products including chapathi.

Unit-6. Legumes, oilseeds and pulses: composition, anti-nutritional factors, processing and storage; Oil Seeds: production of edible oil, meal, flour and other by-products. Oil refining & hydrogenation. Different high protein products based on legumes and oilseeds using latest technologies such as extrusion, flaking etc.

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. Preparation of biscuits
9. Dough rheology
10. Estimation of gluten content, Amylographic studies, Starch damage etc

Course Outcomes

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

CO1: Aware the importance of physico-chemical properties, composition and milling operations for food grains

CO2: Identify the problems associated with milling of grains and their solution

CO3: Know processing food grains into value added products.

Text Books

1. Hoseney RS. 1994. *Principles of Cereal Science and Technology*. 2nd Ed. AACC.

2. Salunkhe DK.1992. *World Oilseeds: Chemistry, Technology and Utilization*. VNR.

Reference Books

1. Chakrabarty MM. 2003. Chemistry and Technology of Oils and Fats. Prentice Hall.

2. Dendy DAV &Dobraszczyk BJ. 2001. Cereal and Cereal Products. Aspen.

3. Kulp K & Ponte GJ. 2000. Handbook of Cereal Science and Technology. 2nd Ed. Marcel Dekker.

4. Lorenz KL.1991. Handbook of Cereal Science and Technology. Marcel Dekker.

5. Marshall WE & Wadsworth JI. 1994. Rice Science and Technology. Marcel Dekker.

6. Mathews RH. 1989. Legumes Chemistry, Technology and Human Nutrition. Marcel Dekker.

7. Dubey SC. 2002. Basic Baking. The Society of Indian Bakers, New Delhi.
8. Francis FJ. 2000. Wiley Encyclopedia of Food Science & Technology. John Wiley & Sons.
9. Manley D. 2000. Technology of Biscuits, Crackers & Cookies. 2nd Ed. CRC Press.
10. Pyler EJ. Bakery Science & Technology. 3rd Ed. Vols. I, II. Sosland Publ.
11. Qarooni J. 1996. Flat Bread Technology. Chapman & Hall.

Course Code	Course Name	L – T – P	**Credits**
ACFT 512	**TECHNOLOGY OF MEAT, POULTRY AND FISH PROCESSING**	3-0-1	**4**

Course Objectives:

- To give knowledge about structure, composition and nutritive value of meat, fish, egg and poultry.
- To develop in-depth knowhow about scientific slaughtering of animals, post mortem changes in them; handling, storage, and transportation of fish, and processing of meat, fish and poultry products.
- To provide insight into the functions and areas of responsibility of meat inspection

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, By-product utilization.

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. Restructured and designed meat products. intermediate moisture and dried meat products; meat plant hygiene – GMP and HACCP; Packaging of meat products.

Unit-2. Poultry: classification, composition, preservation methods and processing. Poultry industry in India, measuring the yields and 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, Whole egg powder, Egg yolk products, their manufacture, packaging and storage.

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; preservation of postharvest fish freshness; 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.

Unit-4. Alternative Protein: Lab grown/cultivated meat.

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. Shelf-life studies on processed meat products;
6. Evaluation of quality of eggs;
7. Preservation of shell eggs;
8. Estimation of meat:bone ratios;
9. Preparation of meat products- barbecued sausages, loaves, burger, fish finger;
10. Application of meat testing kits for quality evaluation.
11. Visit to meat processing plants / modern abattoir

Course Outcomes
After completing this course, the students will be able to: **CO1:** Learn about the scope of meat industry structure, chemical composition, and nutritive value of meat and gain knowledge of various changes in postmortem, meat cut, meat tenderization and utilization of by-products. **CO2:** Understand preservation techniques used for meat and poultry and also learn about transportation processing and preservation techniques. **CO3:** Gain knowledge of poultry chemical composition and nutritive value of poultry and learn about ante and post-mortem examination, methods of stunning, slaughter, scalding and dressing and utilization of poultry by products.
Text Books
1. Lawrie, R.A. 2006. Meat Science, 7th Edn. Pergamon Press, Oxford UK.
Reference Books
1. Fidel Toldrá. 2010. Handbook of Meat Processing. Blackwell Publishing, USA. 2. Legarreta IG & Hui Y.H. 2010. Handbook of Poultry Science and Technology, Wiley Publications. 3. Stadelmen, W.J. and Cotterill, O.J., 1995. Egg. Science and Technology. Fourth Edition. by CRC Press. 4. Mead G. 2004. Poultry Meat Processing and Quality, Woodhead Publishing, CRC Press, Boca Raton, New York. 5. Kerry, Kerry &Ledward. 2002. Meat Processing, Woodhead Publishing, CRC Press, Boca Raton, New York. 6. Hui YH. 2001. *Meat Science and Applications*. Marcel Dekker. 32 7. Pearson AM & Gillett TA. 1996. *Processed Meat*. 3rd Ed. Chapman & Hall. 8. Stadelman WJ &Cotterill OJ. 2002. *Egg Science and Technology*. 4th Ed. CBS publications, New Delhi. 9. Bremner H. 2002. Safety and Quality Issues in Fish Processing. Publishing, CRC Press, Boca Raton, New York. 10. Pearson A. M and **Dutso**n T. R. 1995. HACCP in Meat, Poultry, and Fish Processing. Springer Science+Business Media Dordrecht, U.K.

Course Code	Course Name	L – T – P	**Credits**
ACFT 513	**FOOD PACKAGING TECHNOLOGY**	3-0-1	**4**

Course Objectives:

- To acquaint the students with knowledge about goal of food packaging to satisfy industry requirements and consumer desires, maintains food safety, and minimizes environmental impact.
- To acquaint with various food packaging materials
- To help the student understand various aspects of packaging methods and technology including futuristic technologies in this field.

Course Contents

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: Polyethylene, polypropylene, polyester, polyamides, polycarbonates and vinyl polymers used in packaging, their chemical structure and properties.

Unit-2.

Manufacture of flexible films: Blown film extrusion, cast film extrusion, film orientation process, co-extrusion process, conversion process. Container manufacture - sheet thermoforming, injection moulding.

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 its measurement, prediction of shelf life of foods using different packaging materials.

Transport worthiness tests: Drop test, vibration test, compression strength and rolling test.

Migration from packaging materials: Overall and specific migration, physical process, partition coefficient and sorption process, determination of migration, food simulants, flavour adsorption and sorption, packaging flavour interaction, factors affecting flavour absorption, role of food matrix, flavour modifications and food quality.

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: aesthetic and graphic design; Coding and marking; nutrition labelling, Traceability: RFID tag, bar coding, QR code.

Packaging Laws and regulations: safety aspects of packaging materials,
Environmental & Economic issues, 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 Outcomes

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

CO1: Define different packaging materials and technologies

CO2: Explain the relationship between the packaging materials/technologies and food spoilage;

CO3: Explain food and drink labelling and packaging legislations, migration, permeability and recycling.

Text Books	
1.	Kadoya T. (Ed). 1990. Food Packaging, Academic Press INC.
2.	Robertson, G.L. 2006 Food Packaging: Principles and Practice (2nd ed.), Taylor & Fra
Reference Books	
1.	Mahadeviah M & Gowramma RV. 1996. Food Packaging Materials, Tata McGraw Hil
2.	Gowariker, V.R., Viswanatahan, N. V, Sreedhar, J. 1986, Polymer Science, New International (P) Ltd, New Delhi.
3.	Ahvenainen, R. (Ed.) 2003, Novel Food Packaging Techniques, CRC Press.
4.	Han, J.H. (Ed.) 2005, Innovations in Food Packaging, Elsevier Academic Press.
5.	Yam, K. L, Lee, D. S. (Ed.), 2012, Emerging Food Packaging Technologies: Principle Practice, Woodhead Publishing Ltd.

SEMISTER IV

Course Code	Course Name	L – T – P	**Credits**
RP 542	**PROJECT WORK**		**16**

Course Objectives:

- The aims of this course is to teach the students about planning, execution and reporting a research based study appropriate to their aspirations and chosen field of work within the Food Technology sphere
- The course aims to help the students to develop aptitude for research, learn to formulate hypothesis and design experiments to test the hypothesis.
- The research accomplished in their project work shall make them understand the relevance of food technology in addressing the nutrition, safety, sustainability problems and finding out technological solutions.

Course Outcomes

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

CO1: Plan and execute a research-based study using methodological approach under the guidance of mentor.

CO2: Demonstrate an ability to critically analyse current and futuristic technological advancements in the field of food technology.

CO3: Communicate the work effectively and professionally to a specialist and non-specialist audience.

ELECTIVE I

Course Code	Course Name	L – T – P	**Credits**
ACFT 515	**ADVANCED FOOD TECHNOLOGY**	3-0-1	**4**

Course Objectives:

- To develop understanding of technological advancements to suite food processing industrial needs.
- Emphasis on applied aspects of Food Processing and Packaging
- To groom aptitude of students in the field of research and well as industries by using innovative food Preparation, Processing, Storage methods.

Course Contents

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 CO_2 processing, O_3 (Ozone) processing ,Electron beam processing, Pulsed light processing, Ultrasonication. 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.

Course Outcomes

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

CO1: Apply knowledge gained in food chemistry, microbiology, engineering, and sensory evaluation to the development, processing, and preservation of safe, nutritious, and high-quality food products

CO2: Utilize advanced instruments and technologies to process and analyze food products and to solve food safety problems.

Reference Books

1. Joslyn, M.A. Ed. 1970. Methods in Food Analysis. Academic Press, New York.
2. King, R.D. Ed. 1978. Developments in Food Analysis Techniques-1. Applied Science Publishers Ltd., London.

3. Morris, C.J. and Morris, P. 1976. Separation Methods in Biochemistry 2nd Ed. Pitman Pub., London.
4. Plummer, D.T. 1971. An Introduction to Practical Biochemistry. Mc-Graw Hill Pub. Co., New York.
5. Barbosa-Canovas, G.V., Pothakamury, U.R., Palou, E., Swanson, B.G. 1998. Non Thermal Preservation of Foods. Marcel Dekker, Inc. New York, Basel, Hong Kong.
6. Joslyn, M.A. Ed. 1970.Methods in Food Analysis. Academic Press, New York.
7. Raghuramulu, N., Madhavan Nair, K., and Kalyanasundaram, S. Ed.1983. A Manualof Laboratory Techniques. National Institute of Nutrition, ICMR, Hyderabad.
8. Fellows, P. and Ellis H. 1990. Food Processing Technology: Principles and Practice, New York.
9. Tatiana Koutchma, Larry J. Forney, Carmen I. Moraru, Ultraviolet Light in Food Technology: Principles and Applications, CRC Press, Boca Raotn 2009.
10. Awuah,G. B. Ramaswamy, H. S. ,Tang, J. Radio-Frequency Heating in Food Processing: Principles and Applications, CRC Press, Boca Raotn 2009.
11. Datta, Ashim K. Handbook of Microwave Technology for Food Application, Marcel Dekker Inc. New York 2001.

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 majorcharacterization 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
- Brinnel and Rockwell Hardness Tester
- Automatic grinding and polishing machines
- Optical polarizable microscope with image analyzer
- 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, CranfieldUniversity, 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. or equivalent in any branch of science/mathematics or BE/B.Tech in any branch of Engineering. Also, the student should have a mathematics subject in 12th standard.

Organization:

The program is of four-semester duration. In each semester (first, second, and third semester), students have to undergo 5 courses excluding the last semester. In the fourth semester, students will have to perform project work. In the third semester, students have the option to choose elective courses. In the first, second, and third semesters, there will be continuous evaluation which may comprise several tests/quizzes (decided by the concerned instructor/s) 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 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	MS 501	**Structure and Properties of Materials**	3	0	2	4
2	MS 502	**Materials Characterization Techniques**	3	0	2	4
3	MS 503	**Thermodynamics, Kinetics, and Phase Transformations**	3	1	0	4
4	MS 504	**Polymer Synthesis, Manufacturing, and Technology**	3	0	2	4
5	MS 505	**Computational Mathematics**	3	1	0	4
6	RM 501	**Research Methodology**	3	1	0	4
		Total				**24**

Total credit --24

Semester II

Sr. No.	Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
			L	**T**	**P**	
1	MS 506	**Processing of Metals and Ceramics**	3	0	2	4
2	MS 507	**Principles of Metallurgy**	3	1	0	4
3	MS 508	**Non-destructive Testing**	3	0	2	4
4	MS 509	**Polymer Processing and Rheology**	3	1	0	4
5	MS 510	**Computational Materials Science**	3	1	0	4
6	OJT/FP	**On-Job Training/Field Project**	0	0	8	4
		Total				**24**

Total credit --24

Semester III

Sr. No.	Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
			L	**T**	**P**	
1	MS 511	**Composite Materials and Polymer Blends**	3	1	0	4
2	MS 512	**Additive Manufacturing of Materials**	3	1	0	4
3	RP 541	**Minor Project**	0	0	8	4
4		**Elective I**	3	0/1	0/2	4
5		**Open Elective II**	3	0/1	0/2	4
		Total				**20**

Total credit --20

Semester IV

Sr. No.	Course Code	Subjects (Theory/Practical)	Contact Hours		Credits
			L	T/P	
1	RP 542	**Dissertation**	0	28	14

Total credit – 14

List of Electives

Sr. No.	Course Code	Name of the Course
Electives from the Department		
1	MS 514	Polymer Characterization and Testing
2	MS 515	Nanoscience and Nanotechnology
3	MS 516	Chemistry of Polymer
4	MS 517	Biomaterials
5	MS 518	Functional Materials
7		Open Elective Course#

#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.

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS501	**Structure and Properties of Materials**	3	0	2	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 equillibria 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, JohnWiley& 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: VanVlack*
- *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	0	2	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: Optical microscopy, concepts of magnification, resolution and depth of focus, types of optical microscopy, sample preparation, SEM: imaging modes, image contrast, illustrative applications, EDS, 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: phase identification, strain and grain size determination **Unit III:** Spectroscopic Techniques- Fundamental basis of Spectroscopic analysis, UV-Vis, IR and Raman, X-ray Photon Spectroscopy and Auger electron spectroscopy **Unit IV:** Thermal Analysis Techniques- DSC, DTA and TGA **Unit V:** Lab in microscopy and X-ray techniques, Tensile test, hardness measurement, electrical conductivity, carrier mobility and concentrations.
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/ Practical)	Contact Hours			Credits
		L	**T**	**P**	
MS503	**Thermodynamics, Kinetics, and Phase Transformations**	3	1	0	4

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
• *M. Modell and R.C. Reid, Thermodynamics and its Applications, Prentice-Hall, Englewood Cliffs, New Jersey, 1983.* • *H.B. Callen, Thermodynamics and an Introduction to Thermostatics, Jonh Wiley & Sons, New York, 1985.* • *R.T. DeHoff, Thermodynamics in Materials Science, McGraw-Hill, Singapore, 1993* • *Richard E. Dickerson, Molecular Thermodynamics, W. A. Benjamin, 1969*

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS504	**Polymer Synthesis, Manufacturing, and Technology**	3	0	2	4

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: PE, PP, PS, PVC, Polyesters, Acrylic, PU polymers. Engineering Plastics: Nylon, PC, PBT, PSU, PPO, ABS, Fluoropolymers Thermosetting polymers: Polyurethane, PF, MF, UF, Epoxy, Unsaturated polyester, Alkyds. **Unit II:** Natural and synthetic rubbers: Recovery of NR hydrocarbon from latex; SBR, Nitrile, CR, CSM, EPDM, IIR, BR, Silicone, TPE **Unit III:** Speciality plastics: PEK, PEEK, PPS, PSU, PES etc. **Unit IV:** Biopolymers such as PLA, PHA/PHB. **Unit 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 equipments, cross-linking and vulcanization, vulcanization kinetics
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 and kinetics
Text Book(s) • *Plastics Materials, 7th Edition, J. A. Brydson, Elsevier*
<u>Reference Books:</u> • *Textbook of Polymer Science, Fred W. Billmeyer (Wiley)* • *Polymer alloys and blends by L AUtracki* • *Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)*

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS505	**Computational Mathematics**	3	1	0	4

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	
MS506	**Processing of Metals and Ceramics**	3	0	2	4

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	**Principles of Metallurgy**	3	1	0	4
Course Objectives: • To introduce metallurgical principles of phase transformations and microstructure evolution of various metals and alloys • To introduce strengthening mechanisms, defects, and phases in metals and alloys • To introduce the concepts of strength of materials and techniques					
Unit I: Phase diagrams, Phase Transformation, and Microstructures of Al alloys and steel **Unit II:** Heat Treatment of steel and Al alloys, TTT and CCT diagram. **Unit III:** Defects and plastic deformation phenomenon **Unit IV:** Recovery, Recrystallization and Grain growth **Unit V:** Strengthening of metals and alloys					
Course Outcomes **CO1:** Identify the defects in metals and phases in Fe-FeC diagram with TTT and CCT diagrams **CO2:** Analysis of defects transfer in crystal structure **CO3:** Concept of several strengthening mechanisms **CO4:** Cognizance of strength testing in materials and dependent phenomenon **CO5:** Case studies of metallurgy testing techniques					
Text/Reference Books: • *Introduction to Physical Metallurgy, S H Avner, TATA Mc-Graw Hill, New Delhi, 2001.* • *Morden Physical Metallurgy, 8th Ed, R.E. Smallman, A.H.W. NGAN, Butterworth Heinemann publications, 2014 417* • *Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986* • *Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors*					

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	**T**	**P**	
MS508	**Non-destructive Testing**	3	0	2	4

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)

- *Non-destructive Testing of welds, Baldev Raj, C.V. Subramanian and T. Jayakumar, Narosa Publishing House, 2000, Delhi.*

Reference book(s)

- *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	Subjects (Theory/Practical)	Contact Hours			Credits
		L	**T**	**P**	
MS509	**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/Practical)	Contact Hours L	T	P	Credits
MS510	**Computational Materials Science**	3	1	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):

- *Introduction to Computational Science: Modeling and Simulation for the Sciences, Princeton University Press, A. B. Shiflet and G. W. Shiflet*
- *Introduction to Computational Materials Science – Richard LeSar, Cambridge University Press*

Reference Book(s):

- *Computational Materials Engineering: An Introduction to Microstructure Evolution, Elsevier Academic press, K. G. F. Janssens, D. Raabe, E. Kozeschnik, M. A. Miodownik, B. Nestler*
- *David V. Hutton, Fundamentals of Finite Element Analysis*
- *Mathematic physics (V. Balakrishnan)*
- *Numerical Recipes in C(William H. Press, Vetterling, Teutolsky, Flannery)*

Course Code	Subjects (Theory/Practical)	Contact Hours			Credits
		L	T	P	
MS511	**Composite Materials and Polymer Blends**	3	1	0	4

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 AUtracki*

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.*

Course Code	**Subjects (Theory/Practical)**	**Contact Hours**			**Credits**
		L	**T**	**P**	
MS512	**Additive Manufacturing of Materials**	3	1	0	4

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.*
- *Dougles Bryden, "CAD and Prototyping for Product Design", 2014*

Course Name: Mini Project
Course Code: MS513

Mini project on selected Topic.

Course Name: Polymer Characterization and Testing
Course Code: MS514
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:

- *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 Name: Nanoscience and Nanotechnology
Course Code: MS515

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: MS516

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 AUtracki*
- *Polymer nanocomposites: processing, characterization, and applications by Josheph H. Koo (McGraw-Hill Nanoscience and Technology)*

Course Name: Biomaterials
Course Code: MS517

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 Springer423*

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 Name: Functional Materials
Course Code: MS518

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*

M. Sc. in Applied Chemistry

DEPARTMENT OF APPLIED CHEMISTRY

M.Sc. in Applied Chemistry

SEMESTER I					
No	**Course Code**	**Course**	**L**	**T/P**	**Credit**
1	AC 501	Inorganic Chemistry-I	3	1	4
2	AC 502	Organic Chemistry-I	3	1	4
3	AC 503	Physical Chemistry-I	3	1	4
4	AC 504	Analytical Chemistry	3	1	4
5	AC 541	Applied Chemistry Laboratory-I	-	4	2
6	RM 501	Research Methodology	4	-	4
SEMESTER II					
1	AC 505	Inorganic Chemistry-II	3	1	4
2	AC 506	Organic Chemistry –II	3	1	4
3	AC 507	Physical Chemistry-II	3	1	4
4	AC 508	Polymer Chemistry	3	1	4
5	AC 542	Applied Chemistry Laboratory-II	-	4	2
6	OJT/FP	On Job Training/Internship/Field Project		8	4
SEMESTER III					
1	AC 509	Organometallic Chemistry and Catalysis	3	1	4
2	AC 510	Industrial Chemistry	3	1	4
3	RP 541	Minor Project	3	1	4
4		Elective I	3	1	4
5		Elective II	-	8	4
SEMESTER IV					
1	AC 550	Seminar	-	2	2
2	RP 542	Major Project	-	36	18
		Credits Total			**84**

LIST OF ELECTIVE COURSES

S. No.	Course Code	Course
1	NT 601	Introduction to Nanoscience and Technology
2	AC 610	Recent Advances in Chemistry
3	AC 511	Molecular Spectroscopy I
4	AC 512	Molecular Spectroscopy II
5	AC 513	Defence Chemistry
6	MS 502	Advanced Characterization Techniques
7	NT 604	Nano-biotechnology
8	ACFT 501	Food Chemistry
9	AC 608	Safety Health and Hazard Management
10		Online courses from NPTEL, MOOC. SWAYAM
11		Open elective from any Department

DETAILED SYLLABUS OF SEMESTER -I

Course Code	Course Name	L – T – P	**Credits**
AC 501	**INORGANIC CHEMISTRY-I**	4-0-0	**4**

Course Objectives:

CO 1: To develop an insight into the basic knowledge of inorganic chemistry

CO 2: To understand chemical bonding, coordination compounds, f-block elements and their theories

CO 3: 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

Course Contents

UNIT I: MAIN GROUP ELEMENTS

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

UNIT II: TRANSITION ELEMENTS

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 bond.

UNIT III: LANTHANIDES AND ACTINIDES

Recovery, Periodic properties, spectra and magnetic properties.

UNIT IV APPLICATION OF INORGANIC CHEMISTRY IN INDUSTRY

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:
CO1: To understand structure and bonding of main group elements,
CO2: Students can familiarize with transition metals and their applications
CO3: To understand the basic properties of rare earth elements
CO4: Use of inorganic chemistry knowledge for application in Industry **(heavy inorganics and fertilizers)**
CO5: 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	L – T – P	**Credits**
AC 502	**ORGANIC CHEMISTRY-I**	4-0-0	**4**

Course Objectives:
CO 1: To develop an insight the basic knowledge of organic chemistry
CO 2: To understand structure and reactivity, aromatic nucleophilic substution, stereochemistry of compounds
CO 3: To apply the knowledge and understanding in the areas of structure and reactivity, aromatic nucleophilic substution, stereochemistry of organic compounds for solving existing challenges faced in various chemical and industrial areas

Course Contents

UNIT I: STEREOCHEMISTRY

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.

UNIT II: REACTION MECHANISMS

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), desymmetrization 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:

CO 1. To understand the detailed aspects of Stereochemistry including optical and geometrical isomerism.

CO 2. To gain knowledge on methods of determination of reaction mechanism, various reaction intermediates

CO 3: 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	L – T – P	**Credits**
AC 503	**PHYSICAL CHEMISTRY-I**	4-0-0	**4**

Course Objectives:

CO 1: The learners should be able to apply principles and laws of equilibrium thermodynamics to multicomponent systems. In addition, they should be able to use spectroscopic data to calculate thermodynamic properties of ideal gases, real gases, solids and metals using the principles and techniques of statistical thermodynamics.

Course Contents

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. Gibbs Duhem Margules equation and its applications.

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, Potentiometric and conductometric titrations. Phase rule. Clausius- Clapeyron equation. Phase diagram of one component systems: CO_2, H_2O, 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: **CO1: Understanding of basic chemical thermodynamics** **CO2: To familiarize equilibrium and non-equilibrium thermodynamics** **CO3: 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	L – T – P	**Credits**
AC 504	**ANALYTICAL CHEMISTRY**	4-0-0	**4**
Course Objectives: Students will gain an idea about the chromatography, different kinds of titrations methods, Spectroscopic instrumental method of analysis			
Course Contents **Unit I: Concepts of Analytical Chemistry** 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, monochromator functioning, effective band width, detectors and description of diode array type detector. Atomic Absorption Spectrometry: Principle, interferences, use of electro thermal analyser, hydride generator and cold vapour for trace metal analysis.			

Unit II: Electro-analytical techniques

Electrochemistry, Nernst equation, Potentiometry, Amperometry, Electrochemical analysis, Standard hydrogen electrode (SHE), Calomel electrode, Ion selective electrodes (ISE), etc.and their applications.

Unit III: Spectrochemical methods

Introduction, electronic spectra and molecular structure, Concepts of optical methods: Electromagnetic spectrum, transitions, components in optical instruments, General instrumentation for for spectrometer, Absorbance and chromophores, Beer-Lambert's Law.

Unit IV: Thermal Analysis

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:
CO1:To understand the basic concepts of analytical chemistry
CO2: To understand various types of spectroscopic techniques and their applications
CO3: To thermal analysis
CO4: To understand the detailed aspects of various separation methods (Chromatographic techniques).

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	L – T – P	**Credits**
AC 541	**APPLIED CHEMISTRY LABORATORY-I**	0-0-4	**2**

Course Objectives: students will gain the knowledge of performing experiments including synthesis & characterization and properties

Course Contents

Synthesis, Purification and Analysis of the following Inorganic Preparations:

1. Bis(ethylene-di-ammine) copper (II) sulphate
2. Hexa-ammine nickel (II) chloride/sulphate

Non-Instrumental Experiments: Thermodynamics, Phase Rule and Reaction Kinetics:

1. Determination of heat of solution of benzoic acid by solubility measurements.
2. Determination of heat of solution of salicylic acid by solubility measurements.
3. Determination of equilibrium constant of the reaction KI + I_2+ KI3 by distribution method.

IV. Synthesis of Organic compounds Synthesis, purification and characterization of about ten organic compounds involving one or two stages.

1. m-dinitrobenzene from Nitrobenzene
2. Aromatic acid from ester
3. Benzanilide from aniline
4. p-nitroaniline from Acetanilide
5. Phthalimide from phthalic acid
6. Benzanilide from Benzophenone

Course Outcomes

After completing this course, the students will be able to:
CO1: To perform synthesis, purification and analysis of Organic and Inorganic Compounds
CO2: To study various physic-chemical properties of mixtures

Selected Text Books

1. Elias, A.J., A Collection of Interesting General Chemistry Experiments, Universities 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. l.G., Svehla, 'Vogel's Qualitative Inorganic Analysis',6thEdn., Orient Longman New Delhi, l987.
4. V.V., Ramanujam, 'Inorganic Semi-micro Qualitative Analysis', 3rd Edn., National Publishing Company, Madras, l990.
5. A. I. Vogel, Vogel's Text Book of Quantitative Inorganic Analysis, 6th Ed., Pearson Education, 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	L – T – P	**Credits**
AC 505	**INORGANIC CHEMISTRY-II**	4-0-0	**4**

Course Objectives: students will gain the knowledge Bioinorganic Chemistry and its biological applications.

Course Contents

UNIT I:. BIO-INORGANIC CHEMISTRY

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 tracemet

Sidrophore, phytosidrophores, ferretin, transferrin, hemosiderine, biomineralization, assembly of advanced materials e.g. calcium phosphate, calcium carbonate, ironbiominerals. Oxygen transport and storage through hemoglobin and myglobin, 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: Macrocycle, nucleobase, nucleotides and nucleic acids, coordination of metals by protein. Heme and nonheme protein, oxygen uptake, structure and function of haemoglobin, myoglobin, hemocyanin, hemotherine Principle involved and role of various metals viz. Zn, Fe, Cu and Co; carboxy peptidase, carbonic anhydrase, Alcohol dehydrogenase, Zinc Fingures, other gene regulatory Zinc proteins, cobalomine, mutase activities of coenzyme B12.

UNIT IV: APPLICATIONS OF BIO-INORGANIC CHEMISTRY

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:
CO1: The concept of Bioinorganic Chemistry and its biological applications
CO2: To understand photosynthesis and other photochemical reactions
CO3: Role of bioinorganic chemistry in nature
CO4: Important Applications of Bio-inorganic chemistry

Text Books

1. The Organometallic Chemistry of the Transition Metals, by 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 Chemistry – Principles of Structure & Reactivity, J E Huheey, Elllen A Keiter &

Reference Books

5. Richard L Keiter, IV Edition(2005)

Course Code	Course Name	L – T – P	**Credits**
AC 506	**ORGANIC CHEMISTRY-II**	4-0-0	**4**

Course Objectives:
To impart advanced knowledge of reactive intermediates, stereochemistry of organic compounds, pericyclic reactions, heterocyclic compounds and applications in biomolecules

Course Contents

UNIT I: PERICYCLIC REACTIONS AND PHOTOCHEMISTRY

Electrocyclic, cycloaddition 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 iso quinoline.

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:
CO1: Understanding of Electrocylcic/cycloadditions and sigmatropic reactions
CO2: To understand photo-oxidation and photo reduction and related rearrangements
CO3: To understand heterocylic and their applications in biomolecules and drugs
CO4: 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 6.
Reference Books
Organic Photochemistry – James H. Coxon, B. Halton

Course Code	Course Name	L – T – P	**Credits**
AC 507	**PHYSICAL CHEMISTRY-II**	4-0-0	**4**

Course Objectives: To apply the knowledge and understanding in the areas of solid state chemistry, chemical kinetics and surface chemistry for solving existing challenges faced in various chemical and industrial areas also To understand various phenomena of group theory and spectroscopy.

Course Contents

UNIT I: CHEMICAL KINETICS

Elementary, parallel, opposing and consecutive reactions. Steady state approximation. Mechanisms of complex reactions. Unimolecular 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 inhibiton-reversibility and products inhibiton, 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 unimolecular 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: GROUP THEORY

Symmetry Elements and Symmetry Operations, Point Groups, Representation of Groups, Reducible and Irreducible Representation; Character Tables, Orthogonality Theorem– Its Consequences; Internal coordinates and vibrational modes; symmetry adapted linear combination of atomic orbitals (LCAO-MO);

Course Outcomes

After completing this course, the students will be able to:
CO1: Understanding rate laws based on Chemical Kinetics
CO2: Understanding different aspects of surface chemistry
CO3: 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	L – T – P	**Credits**
AC 508	**POLYMER CHEMISTRY**	4-0-0	**4**

Course Objectives: To understand fundamental concepts and techniques in polymer chemistry including reaction mechanism and commercial applications

Course Contents

UNIT I: FUNDAMENTAL CONCEPTS

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 - Mn, Mw, Mv and Mz - 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 Tg.

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-vinyles 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: **CO1:** To understand fundamental concepts and techniques in polymer chemistry **CO2:** Methods of characterization of polymers. **CO3:** learn various important polymers. **CO4:** Familiarize polymers having commercial applications
Text Books
1. P.J. Flory, 'Principles of Polymer Chemistry', Cornell Press, (Recent Edition). 2. Jr. Billmeyer, 'Test Book of Polymer Science', Fred, W. John Wiley & Sons, N. York, l984. 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., l982. 5. K.J. Saunders, 'Organic Polymer Chemistry', Chapman & Hall, London, l973.
Reference Books
1. 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	L – T – P	**Credits**
AC 542	**APPLIED CHEMISTRY LABORATORY - II**	0-0-8	**2**
Course Objectives: To acquire basic knowledge of various instrumental methods of analysis and synthesis with their characterization			
Course Contents 1. pH metry / conductometry / potentiometry and precipitation titrations 2. Determination of critical miceller concentration of surfactants.			

3. Preparation and TLC demonstration of the purified product and determination of MP and % yields, etc. 1. Bromobenzene to p-nitro bromobenzene 2. Nitrobenzene to m-dinitrobromobenzene 3. Benzoin to Benzil 4. Anthracene to Anthraquinone 5. Anthracene-Maleic Anhydride adduct
Course Outcomes
After completing this course, the students will be able to: **CO1:** To familiarize various electro-analytical/optical techniques **CO2:** Synthesis and characterization of organic compounds
Text Books
Reference Books
1. Elementary Practical Organic Chemistry Part-I small scale preparations, A.L. Vogel (Longman) 2. Laboratory Manual of organic chemistry, B.B. Dey and M.V. Sitaram revised by T.R Govindachari (Allied Publishers Ltd) 3. D.P.Shoemaker, C.W.Garland & J.W.Nibber,,‘Experiments in Physical Chemistry’, McGraw Hill 5th Edn., 1989. 4. A. I. Vogel, ‘Text book of Practical Organic Chemistry’,5thEdn. ELBS, London, l989. 5. B.B.Dey and M.V.Sitharaman,‘Laboratory Manual of Organic Chemistry’ Revised by T.R. Govindachari, Allied Publishers Ltd., New Delhi. 4th Revised Edn. l992.

DETAILED SYLLABUS OF SEMESTER -III

Course Code	Course Name	L – T – P	**Credits**
AC 509	**ORGANOMETALLIC CHEMISTRY AND CATALYSIS**	3-0-2	**4**
Course Objectives: To understand the basic of organometallics and their synthesis , bonding, properties and their applications			

Course Contents

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, cyclopentane, dienyl, arenes. Distinctive organometallic Reactions - Addition and abstraction: Nucleophilic addition to CO, Nucleoplic 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.. Fluxionality and dynamic equilibria,

UNIT III: TRANSITION METALS/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: **CO1:** To understand fundamentals of Organometallic chemistry **CO2:** To familiarize with the synthesis, property studies and application of Organometallic chemistry **CO3:** Applications of Organometallic reagents in Organic Synthesis
Text Books
1. Organometallics: A concise Introduction, Ch.Elshebroicn and A Salzer, VCH, 2006. 2. Organ transition Metal Chemistry: Applications to Organic Synthesis, S.G. Davies, Pergamon 1982.
Reference Books
Basic Organometallic Chemistry, Anil Elias

Course Code	Course Name	L – T – P	**Credits**
AC 510	**INDUSTRIAL CHEMISTRY**	3-0-2	**4**

Course Objectives: To understand the scalability of laboratory reactions in Industry with proper operations and safety.

Course Contents

UNIT I: CHEMICAL INDUSTRY

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

UNIT II: INDUSTRIAL PROCESSES AND THEIR SAFTEY:

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.

Safety in Industry

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 sulphonic acid.

   Esterification: Esterification of organic acids and derivatives, esters by addition, to unsaturated systems, interesterification of lard, technical preparation of ethyl acetate, cellulose acetate, nitroglycerol, polyethyl ether.

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, Typical Industrial nitration processes.

Course Outcomes
After completing this course, the students will be able to: **CO1:** To understand the scalability of laboratory reactions in Industry **CO2:** To understand operations and safety in Industrial reactions **CO3:** Indepth 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. 5.
Reference Books
1. Encyclopaedia of Chemical Technology, Kirk and Othmer, John Wiley & Sons, 2000

SYLLLABUS OF ELECTIVE COURSES

Course Code	Course Name	L – T – P	**Credits**
AC 511	MOLECULAR SPECTROSCOPY-I	4-0-0	**4**
Course Objectives: to understand fundamental principles of Spectroscopy and theories involved			

Course Contents

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.

UNIT I: INTRODUCTION TO MOLECULAR SPECTROSCOPY

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.

UNIT II: ATOMIC SPECTRA

Characterization of atomic states. Microstate and spin factoring methods. Hund's rules. Derivation of spin and orbital selection rules (based on recursion relations of Legand re 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.

UNIT IV: VIBRATIONAL SPECTROSCOPY

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:
CO1: To study understand the principles of atomic and molecular spectroscopy
CO2: To understand theory of vibrational spectroscopy

Text Books

BOOKS (MOLECULAR SPECTROSCOPY)

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	L – T – P	**Credits**
AC 512	**MOLECULAR SPECTROSCOPY II**	3-0-2	**4**

Course Objectives:To understand and apply various spectroscopic techniques for characterization

UNIT I: RAMAN SPECTROSCOPY

Stokes and anti-Stokes lines. Polarizability of molecules. Rotational and Vibrational Raman spectroscopy. Selection rules. Polarization of Raman lines.

UNIT II: ELECTRONIC SPECTROSCOPY

Diatomic molecules. Selection rules. Breakdown of selection rules. Franck-Condon factors. Dissociation energies. Photoelectron spectroscopy of diatomic (N2) and simple polyatomic molecules (H2O, 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 ^{1}H 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, Mc Connel relation, 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 PROPERTIED 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:
CO1: To understand the principles of RAMAN spectroscopy
CO2: To understand the principles of electronic spectroscopy
CO3: To understand the principles of NMR spectroscopy
CO4: To understand the principles of Mossbauer spectroscopy

Text Books

Reference Books

Course Code	Course Name	L – T – P	**Credits**
AC 513	**DEFENCE CHEMISTRY**	3-0-2	**4**

Course Objectives: To familiarize students about the utility of chemistry in defence

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

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:
CO1: Study of chemistry of High Energy Materials
CO2: To understand the applications of polymers and nanocomposites in defence
CO3: To familiarize with High strength materials
CO4: 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	L – T – P	**Credits**
AC-610	**RECENT ADVANCES IN CHEMISTRY**	3-0-2	**4**

Course Objectives: To familiarize about various important topics currently practiced in chemistry

UNIT-1. INTRODUCTION

Background and eminent discoveries in Chemical Technology Frontiers in Electrochemistry: Equilibrium properties of electrolytes, electrode potential, electro analytical techniques.

UNIT-2. GREEN CHEMISTRY

Principals of green chemistry, sustainability, selected examples of green synthesis.

Unit-3. Biochemistry & Biotechnology: Cell Biology and Physiology, Bioenergetics, Industrial Biotechnology.

Unit-4. Chemistry of smart materials: 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:
CO1: To familiarize students in important discoveries of chemical technologies
CO2: To understand electrochemical techniques
CO3: To understand biochemistry and biotechnology
CO4: To understand the chemistry of smart materials
CO5:

Text Books

1. Electrochemistry for Chemists, Sawyer, Sobkowiak, & Roberts, John Wiley, 1995.
2. Concepts in Transition Metal Chemistry, Crabb, Eleanor, Moore, Elaine, Smart, Lesley E.RSC Publishing, 2010
3. Highlights in Bioorganic Chemistry, Carsten Schmuck, HelmaWennemers, Wiley-VCH, 2004.

4.
Reference Books
1. Essentials of Pharmaceutical Chemistry, D. Cairns 5. Intelligent Materials, M. Shahinpoor, H.-J. Schneider, RSC, 2008

Course Code	Course Name	L – T – P	**Credits**
AC 611	**QUANTUM CHEMISTRY**	3-0-2	**4**

Course Objectives: The course will train students to understand in-depth the fundamentals of quantum rules and models and their application in chemistry.

UNIT I: QUANTUM CHEMISTRY-I

Basic postulates of Quantum mechanics (a brief review). Operators in Quantum mechanics: Linear and Hermitian operators, Commutation of operators. Differential equations, partial differential equations, series solutions and special functions, linear vector spaces, transformation of coordinate matrix, representation of operators, eigenvalue problem, orthonormal sets, Fourier and Laplace transforms. Some exactly soluble problems. Simple harmonic oscillator problem. Calculation of various average values using ladder operators and recursion relations of Hermite polynomials. Angular momentum operators. Eigenvalues and eigenfunctions. First order time-independent perturbation theory for non-degenerate states. Variation theorem, variational methods and their applications. Ground and excited state of helium atom.

UNIT II: QUANTUM CHEMISTRY-II

Schrodinger equation for hydrogen atom and its solution, the origin of electronic quantum members and physical significance - radial probability density significance of magnetic quantum number with respect to angular momentum. Hydrogen molecule ion and hydrogen molecule Paulis exclusion principle. Term symbols for electronic state in atoms– LS and JJ coupling. Born Oppenheimer approximation, Variational treatment of hydrogen molecule ion. Mulliken designation of molecular orbitals, wave functions for many electron atoms–Hartres–Fock SCF method, Slater Orbitals.

Unit III: Born interpretation. Dirac braket notation. Particle in a box: infinite and finite square wells; concept of tunnelling; particle in 1D, 2D and 3D-box; applications. Harmonic oscillator: harmonic and an harmonic potentials; hermite polynomials. Rotational motion: Angular momentum operators, Rigid rotor. Hydrogen and hydrogen-like atoms: atomic orbitals; radial distribution function. Multi-electron atoms: orbital approximation; electron spin; Pauli exclusion principle; slater determinants. Approximation Methods: Variation method and secular determinants; first order perturbation techniques. Atomic units. Molecular structure and Chemical bonding: Born-Oppenheimer approximation; Valence bond theory and linear combination of atomic orbitals –molecular orbital (LCAO-MO) theory. Hybrid orbitals. Applications of LCAO-MO theory to H_2^+, H_2; molecular orbital theory (MOT) of homo- and heteronuclear diatomic molecules. Hückel approximation and its application to annular π– electron systems.

Course Outcomes

After completing this course, the students will be able to:
CO1: To understand the basics of Quantum Chemistry and various laws in this regard
CO2: Familiarize with important concepts to hypothise quantum mechanics
CO3: To understand important postulates of quantum chemistry

Text Books

1. I. N. Levine, ‘Quantum Chemistry’, 4th Edn., Prentice Hall India, 2001.
2. A. K. Chandra, Introductory Quantum Chemistry, Tata McGraw Hill 1994.
3. M.S. Gopinathan and V. Ramakrishnan, Group Theory in Chemistry, Vishal Publishers,1988.
4. Methods of Molecular Quantum Mechanics by P.W. Atkins.
5. Cotton, F.A. Chemical Applications of Group Theory, 3rd Edn., John Wiley and Sons, 2003.
6. Physical Chemistry: A Molecular Approach by D.A. Mc Quarrie and J.D. Simon
7. D.A. McQuarrie. Quantum Chemistry, Viva Books Pvt Ltd (2003)
8. Jack Simons, Introduction to Theoretical Chemistry, Cambridge University Press, 2003.

Reference Books

P.W. Atkins. Molecular Quantum Mechanics, Oxford University Press (1986)

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 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. The syllabus has been designed as per the guidelines of NEP 2020.

Stakeholders:

(v) Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments

(vi) 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. Course syllabus is updated periodically to keep pace with the contemporary technological advancement.

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: 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's program

PO4: Having adaptive thinking and adaptability in relation to environmental context and sustainable development

PO5: Having a clear understanding of professional and ethical responsibility

PO6: Having a good cognitive load management skill related to project management and finance

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Sc. (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.

Credit Structure (As per NEP 2020)

1 credit = 15 clock hours of teaching or tutorial

1 credit = 30 clock hours of practical

SEMESTER I

Sl. No.	Course Code	Course	Credit distrubution			Total Credits
			L	T	P	
1	AP 501	Quantum Mechanics	3	1		4
2	AP 502	Introduction to Optics & Photonics	3		1	4
3	AP 503	Introduction to Lasers	3		1	4
4	RM 501	Research Methodology	3	1		4
5	AP 505	Basic Photonics Laboratory	0		2	2
6		Elective 1	3	1		4
		Total	**15**	**03**	**4**	**22**

Options for Elective 1:

Choose Anyone						
1	MS 505	Computational Mathematics	3	1		4
2	AM 607	Mathematics of Engineers	3	1		4

SEMESTER II

Sl. No.	Course Code	Course	Credit distribution			Total Credits
			L	T	P	
1	AP 506	Electronic devices and circuits	3		1	4

2	AP 507	Solid State Physics	3	1		4
3	OJT/FP	On-Job Training/Field Project				**4**
4	AP 509	Nanophotonics	3	1		4
5	AP 510	Electronics and Photonics Laboratory	0		2	2
6		Elective 2	3	1		4
		Total	**12**	**03**	**03**	**22**

*** To be completed during the summer vacation (120 Hrs)**

Options for Elective 2:

Choose Any one						
1	AP 631	Laser Applications	3	1		4
2	**AP 508**	Computational Photonics	3	1		4

SEMESTER III

Sl. No.	Course Code	Course	Credit distribution			Total Credits
			L	T	P	
1	AP 624	Semiconductor Photonic devices	3	1		4
2	AP 623	Introduction to Fiber Optics	3	1		4
3	AP 512	Advanced Photonics Laboratory	0		4	4
4	AP 513	Introduction to Programming	0		2	2
5	RP 541	Research Project – 1				**4**
6		Elective 3	3	1		4
		Total	**08**	**02**	**08**	**22**

Options for Elective 3:

Choose Any one						
1	EE 602	Digital Signal processing	3	3		4
2	EE 624	Digital System Design using FPGA	2		2	4

3	AP 514	Introdution ot Biophtonoics	3		1	4

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week			Credits
			L	**T**	**P**	
1	AP 608	Machine learning techniques for sensor data analytics	3	1		4
2	AP 642	Tera Hertz Devices and Applications	3	1		4
3	AP 643	Free Space Optical Communication	3	1		4
4	RP 542	Research Project – II				**6**
5		Elective 4	3	1		4
		Total	**12**	**4**		**22**

Options for Elective 4:

Choose Any one						
1	QT 622	Nonlinear and Quantum Optics	3	1		4
2		NPTEL/MOOC course	3	1		4

UGC recommended courses (Additional 10 credits)

(to be completed by the student/candidate before the completion of the program)

Cyber Security/Information security - 4 credits

Human Rights-I - 1 credit

Human Rights-II - 1 credit

Introduction to Indian Constitution - 2 credits

Skill Development Courses - 2 credits

Semster I Course details

Course Code	Course Name	L – T – P	Credits
AP 501	**Quantum Mechanics**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about formulation in quantum mechanic physics.
- To introduce the fundamental concepts of quantum mechanic physics.
- To enable the students to underrstand quantum mechanics in lasers.

Course Content

Units	Syllabus Details	Hrs
Unit I	Historical Origin of Quantum mechanics: Thermal radiation, Plank's postulates, Black body radiation, stationary states, correspondence principle, Bohr Atom, shortcomings of old quantum theory.	**9**
Unit II	The Schrödinger equation, Statistical interpretation, probability, normalization, momentum, The uncertainty principle	**6**
Unit III	Time Independent Schrödinger: stationary states, infinite square well, harmonic oscillator, free particle, delta function potential, finite square well	**9**
Unit IV	Formalism: Hilbert's space, observables, eigen function of Hermitian operator, statistical interpretation, Dirac notation	**6**
Unit V	One electron atoms: solution of Schrödinger equation in 3D, eigen values, quantum numbers, and degeneracy, orbital angular	8
Unit VI	Quantum statistics: indistinguishability and quantum statistics, quantum distribution functions, Boltzmann distribution as an approximation to quantum distributions, Introduction to Quantum Optics, Coherent States	**7**

Course Outcomes

CO-1	Understand the basic concepts of quantum mechanics Physics
CO-2	Interpret the physical meaning of formulation in quantum mechanics
CO-3	Examine different 1D problems in quantum mechanics
CO-4	Illustrate the implementation to 1 electron atoms
CO-5	Explain Quantum mechanics to Lasers

Text Books

1. Quantum Mechanics, John Powell, Bernd Crasemann, Narosa Publishing House
2. Quantum Mechanics, Leonard Schiff, Mc-Graw Hill Book Company
3. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing

Reference Books
1. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing 2. Quantum Mechanics by B H Bransden and C J Joachain Pearson Publishing

Course Code	Course Name	L – T – P	Credits
AP 502	**Introduction to Optics and Photonics**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge about formulation in quantum mechanic physics.
- To introduce the fundamental concepts of quantum mechanic physics.
- To enable the students to underrstand quantum mechanics in lasers.

Course Content

Units	Syllabus Details	Hrs
Unit I	**Fundamentals of Photonics and Optics:** Wave equation, Plane waves, Applications of photonics, Reflection and Refraction of plane waves, Fresnel Equations, Wave propagation in different mediums, propagation of Electromagnetic waves in Uniaxial and biaxial crystals, the dielectric constant tensor and the 'index ellipsoid'	**9**
Unit II	**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: polarizing and non-polarizing, wavelength filters, dichroic mirrors, Lenses.	**10**
Unit III	**Electro-optics:** Basic principles: Pockel and Kerr effects, Electro-optic devices: modulators, switches, and scanners, E.O. effect in liquid crystals; LCDs and SLMs, Applications.	**9**
Unit IV	**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 acoustooptictunable filters.	**9**
Unit V	**Magneto-optics**: Principles, Faraday effect, Gyrotropic permittivity, Kerr rotation and Kerr ellipticity, Applications.	8

Course Outcomes	
CO-1	Interpret the concepts of optical electronics
CO-2	Analyze the working principle of ME Theory, EO, MO and AO effects
CO-3	Examine the working mechanism of different types of Optical components, EO, MO and AO eff
CO-4	Illustrate the practical use of Optical components, EO, MO and AO effects
CO-5	Summarize different applications of optical electronics devices

Text Books

4. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press,1989. References
5. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006.
6. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
7. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000.

Reference Books

1. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
2. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988.
3. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.

Course Code	Course Name	L – T – P	Credits
AP 503	**Introduction to Lasers**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge about laser technology
- To introduce the fundamental concepts of lasers.
- To enable the students to understand working principle of laser systems

Course Content

Units	Syllabus Details	Hrs
Unit I	**Light-matter interaction:** Interaction of radiation with atomic systems, Einstein's coefficients, spontaneous emission, stimulated emission, Linewidth of the laser	10
Unit II	**Lasers Oscillation**: Theory of laser oscillation; Threshold condition, Rate equation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output power, Pumping techniques.	10
Unit III	**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.	10

Unit IV	**Laser Systems 1:** Solid-state lasers, Gas lasers,	8
Unit V	**Laser Systems 2:** Fiber laser and amplifiers	7

Course Outcomes

CO-1	Interpret the concepts of laser technology
CO-2	Analyze the working principle of lasers
CO-3	Examine the laser radiation beams
CO-4	Illustrate and construct the practical laser systems
CO-5	Summarize different types of laser systems and its working principals

Text Books

4. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.
5. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
6. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988

Reference Books

1. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
2. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).

Course Code	Course Name	L – T – P	Credits
AP 505	**Basic Photonics Laboratory**	**0-0-2**	**2**

Course Objectives:

- To impart practical knowledge about basic electronics
- To introduce the charatceristics of devices
- To enable the students to understand working of optical components

Course Content

Syllabus Details	Hrs
Photonics 1. Measurement of Refractive index using Michelson Interferometer 2. Determination of the Electrical and Optical Characteristics of LED and Laser diode. 3. Experiment on Laser beam cleaning by Spatial Filtering 4. Beam Collimation with different telescopic arrangement 5. Measurement of diameter of thin wire using the laser light diffraction method. 6. Young's Single-slit and Double Slit experiment 7. Determine the lines per inch of a Transmission diffraction grating by its dispersive angles. 8. Detection of polarisation states using polarisation components like polarizers, waveplates etc.	60

9. Analysis of various light source spectra using OSA. 10. Determination of Numerical Aperture and V Number of single mode & multimode fiber. 11. Macro and Microbending loss in optical fibers and its application 12. Measurement of Photodiode characteristics 13. Study of Fraunhofer diffraction pattern of a rectangular and circular aperture. 14. Finding the Verdot's constant by Faraday Effect 15. OptiSystem training module for Optical System Designing	

Course Outcomes

CO-1	To understand basic electronics
CO-2	To interprete characteristics of the devices
CO-3	Examine the working of basic electronic components
CO-4	Illustrate working of optical components
CO-5	Explain difference in diode and Laser characteristics

Course Code	**Course Name**	**L – T – P**	**Credits**
MS 505	**Computational Mathematics**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge about basic mathematics algebra
- To introduce the concept of scientific computations
- To enable the students to use numerical methods to solve differential equations

Course Content

Units	Syllabus Details	Hrs
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.	**9**
Unit II	Calculus of single and multiple variables: Limit, Continuity and differentiability; Maxima and minima – Necessary and sufficient conditions; Partial derivatives; Total derivative	**9**
Unit III	Vector Calculus:	**9**

	Vector Fields; Gradient, divergence and curl; Line integrals, and Green's theorem; Divergence theorem; Physical interpretation of mathematical operations	
Unit IV	Scientific Computing: Concepts of discretization in space/time, implicit, explicit; Taylor's series; Solution to ODEs	**9**
Unit V	Numerical Solution of Differential Equations: Classification of second order linear partial differential equations; Method of separation of variables: One dimensional heat equation and two-dimensional Laplace equation.	**9**

Course Outcomes

CO-1	Understand the basics of Linear Algebra
CO-2	Recognize the principles of Multivariable calculus
CO-3	Apply the principles of Differential and Integral calculus
CO-4	Interpret the concepts of Scientific Computations
CO-5	Implementing numerical methods to solve differential equations

Text Books

- Advanced engineering mathematics: Kreyszig; Wiley.
- Advanced engineering mathematics: Jain/Iyenger; Narosa

Reference Books

- 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

Semster II Course details

Course Code	Course Name	L – T – P	Credits
AP 506	**Electronic Devices and Circuits**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge about basic of semiconductor
- To introduce the concept of s diodes, transistors and oscillators
- To enable the students to undertand working principles of devices

Course Content

Units	Syllabus Details	Hrs
Unit I	Basics of semiconductor and Introduction to Diodes: The energy band theory of crystals, Intrinsic and Extrinsic semiconductors. P-N Junction diode as a Rectifier, Photo-Diode, Filters using Diode, Clipping & clamping circuits, LED, Zener diode	8
Unit II	Transistors and Oscillators: Basics of Transistor, Transistor characteristics and applications, basics of oscillators and multivibrators (IC555 as timer).	10
Unit III	Field Effect Transistor: Structure and working of: JFET, I-V characteristics and parameters (Pinch off voltage, trans conductance, drain resistance, amplification factor); MOSFET (construction and application only) Applications: FET as Voltage Variable resistance (VVR), switch, memory cell, DRAM	10
Unit IV	OPAMPS & Multivibrators : Idea op-amplifier characteristics, Block diagram, Basic Inverting & non inverting amplifier, Basics of oscillator, Basics of Timer IC 555 as astable multivibrator.	10
Unit V	Sequential circuits and Counters: RS, Clocked RS, JK, Master Slave JK, D Flip flop, Counter-synchronous, asynchronous, up-down counter, modulo-N counter, Decade counter (IC 7490); shift register (IC 7495), ring counter	7

Course Outcomes

CO-1	Understand the basics of Semiconductos and Diodes
CO-2	Recognize the principles of Transistoirs ans oscillators
CO-3	principles of Field effet transistor
CO-4	Interpret the concepts of OPAMPS & Multivibrators
CO-5	Implementing circuits in devices

Text Books
1. Millman's Integrated Electronics - Analog and Digital Circuit and Systems | 2nd Edition by Jacob Millman, Christos Halkias, Chetan Parikh 2. Electronic Principles | 7th Edition by Albert Malvino , David J. Bates
Reference Books
1. Roberts L Boylestad & Louis Nashelsky Electronic Devices Circuit Theory

Course Code	**Course Name**	**L – T – P**	**Cred its**
AP 507	**Solid State Physics**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about basic concepts of solid state physics
- To introduce the electronic and magnetic properties of solid state physics
- To enable the students to solve physics problems

Course Content

Units	Syllabus Details	Hrs
Unit I	**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 dislocations.	8
Unit II	**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.	10
Unit III	**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.	10
Unit IV	**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.	10

Unit V	**Magnetism** – Diamagnetism, Langevin equation. Pauli paramagnetism in metals. Paramagnetism –Curie law. Ferromagnetism. Quantum mechanical nature of ferromagnetic interaction. Anti-ferromagnetic and ferromagnetic order.	7

Course Outcomes

CO-1	Understand the basic concepts of Solid State Physics
CO-2	Interpret the physical meaning of formulation in Condensed Mateer
CO-3	Examine different Structure related properties
CO-4	Study the Electronic and magnetic properties of solids
CO-5	Develop skills to solve physics problems

Text Books

1. Introduction to Solid State Physics, Charles Kittel (John Wiley and Sons.).

2. Solid State Physics, A. J. Dekkar (Prentice Hall).

Reference Books

1. Solid State Physics, N. W. Ashcroft and N. D. Mermin (CBS Publishing Asia Ltd.).

Course Code	Course Name	L – T – P	Credits
AP 509	**Nanophotonics**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about basic concepts of solid state physics
- To introduce the electronic and magnetic properties of solid state physics
- To enable the students to solve physics problems

Course Content

Units	Syllabus Details	Hrs
Unit I	Basics of Nanophotonics: Photons and electrons, Quantum confinement effects, 2D, 1D, 0D structures, their growth and properties	**9**
Unit II	**Metamaterials:** Definition of Metamaterials (MTMs) and Left-Handed (LH) MTMs, **Fundamentals of LH MTMs** Left-Handedness from Maxwell's Equations	**9**
Unit III	**Metamaterial in Optics:** Optical Properties of Metal-Dielectric Composites, Optical Magnetism, Negative-refractive Index, Perfect lens and Cloaking objects.	**9**
Unit IV	**Surface Plasmon Resonance:** Evanescent waves, Surface Plasmon dispersion equations, resonance, excitation od surface plsmons, surface Plasmon properties, SPR spectroscopy	**9**

Unit V	**Photonic band gap crystals:** Photonics Band-Gap: Introduction to Photonics crystal, Photonic Band Structures, One dimensional, Photonic crystal: Origin of Photonics Band Gap, Size of the band gap, Evanescent Modes in Photonics Band gaps, Two-dimensional Photonic crystal: Two-dimensional Bloch States, Square Lattices (Dielectric Columns and Veins), Three-dimensional Photonic crystal: Three-dimensional lattices,	**11**

Course Outcomes

CO-1	Familiarization to the concept of Metamaterials
CO-2	Illustration of Optical Properties in Metamaterials
CO-3	Examine Surface Plasmon Resonance
CO-4	Analyze Photonic Bandgap Crystals in different dimensions
CO-5	Understanding the Importance of Silicon Photonics and Its Applications

Text Books

5. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, Christophe Caloz,Tatsuo Itoh, John Wiley and Sons,2006
6. Optical Metamaterials, Fundamentals and Applications, Wenshan Cai Vladimir Shalaev, Springer, 2010.
7. John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, and Robert D. Meade,Photonic Crystal: Molding Light Flow of Light, Princeton University Press, 2008.

Reference Books

1. Graham T. Reed and Andrew P. Knights, Silicon Photonics: An Introduction, JohnWiley and Sons Ltd, 2004
2. Metamaterials: Physics and Engineering Explorations, Nader Engheta Richard W. Ziolkowski, Wiley and Sons,2006
3. Negative-Refraction Metamaterials Fundamental Principles and Applications, G. I. Eleftheriades K. G. Balmain,Wiley and Sons,2005

Course Code	Course Name	L – T – P	Credits
AP 510	**Electronics and Photonics Laboratory**	**0-0-2**	**2**

Course Objectives:

- To impart practical knowledge about basic logic circuits
- To introduce the working of holography
- To enable the students to understand working of fiber optical communication

Course Content

Syllabus Details	Hrs
Electronics: 1. To study the I-V Characteristics of Diodes (Simple and Zener Diode) 2. To study the I-V Characteristics of Transistors in CB, CE, CC modes (NPN and PNP Transistors) 3. To study the I-V Characteristics of MOSFETs 4. To study the Half, Full, and Bridge rectifier 5. To study the Voltage and Current regulation with a fixed load	60 hrs

6. To study the Clipping and clamping Circuit
7. To study the Characteristics of 741 OPAMPs
8. To analyze the inverting and non-inverting amplifier
9. To Design Active filters

Photonics:

1. Beam Width, Divergence, and M^2 measurement of He-Ne/Diode Laser with and without collimation lens.
2. Fiber optic link design
3. Measurement of attenuation and dispersion in optical fibers
4. Fiber to Fiber splicing (SM-SM, SM-MM, MM-MM, PM, etc.) and splicing loss measurement.
5. Setting up of Mach-Zender interferometer
6. Design of driver circuit for LED and Laser diode
7. Characterization of Erbium Doped Fiber Amplifier
8. Simulation of Basic FBG Fiber Loop Mirror Sensor Designing using Optiwave softwave Design of signal conditioning circuits for Photodetectors

Course Outcomes

CO-1	Understand basic logic circuits
CO-2	Analyze the working of A/D and D/A convertors
CO-3	Illustrate the working Holography
CO-4	Examine the losses in fiber optical communication
CO-5	Interprete the working of fiber lasers

Course Code	Course Name	L-T-P	Credits
AP 631	**Laser Applications**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Laser applications.
- To introduces the Holography, Laser Metrology and Laser Spectroscopy
- To enable the students to understand Industrial and defence applications

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**Laser Metrology: Laser** for measurement of distance, length, velocity, acceleration; rotation sensing; RLG and FOG.	**6**
Unit II:	**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**
Unit III	**Holography:** Holographic interferometry and applications; Holography for non – destructive testing – Holographic components	**6**
Unit IV	**Industrial Application of Laser:** Laser cutting, Laser welding, Laser drilling, Laser marking, Photolithography, Laser-based unmanned ground vehicles	**9**
Unit V	**Defence Applications:** Low power laser applications including Laser Range finders-LRF (DPSSL, Eye Safe & High PRF) & Laser Target Designators;	**12**

	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	

Course Outcomes

CO-1:	Familiarize to a variety of applications on lasers
CO-2:	Interpret how laser-based metrological techniques work
CO-3:	Understand laser spectroscopy applications
CO-4:	Investigate various methods of how a laser can be used for defence applications
CO-5:	Summarize different applications of lasers

Text Books

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 Books

1. K. Bharat, Laser Safety Tools and Training, CRC Press 2009
2. K. Nagothu, New Paradigms for Underwater Communication, ProQuest 2009

Course Code	Course Name	L-T-P	Credits
AP 508	**Computational Photonics**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Laser applications.
- To introduces the Holography, Laser Metrology and Laser Spectroscopy
- To enable the students to understand Industrial and defence applications

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**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, plasmonic and microwave waveguides,	9
Unit II:	**Beam Propagation Method:** Theory and working of beam propagation method, Tutorials on MMI couplers, optical gratings, co-directional couplers or polarization converters.	9
Unit III	**FDTD Method:** Theory and working of FDTD method, Tutorials on photonics band gap simulation: 2D and 3D of different crystal lattices.	9
Unit IV	**Fiber Optics Modeling:** Simulation and modeling of single mode and multimode optical fiber using mode solver, FBG and Chirped FBG synthesis, photonic crystal fiber simulation	8
Unit V	**Nanodesign:** Mask designing for nanofabrication of different device geometry	7
Unit VI	**Introduction to Finite Element Method**	3

Course Outcomes

CO-1:	Understand the simulation methos of photonics devices and fiber Optics
CO-2:	Study on mode solution method of photonics devices

CO-3:	Study on beam propagation method for Photonics devices	
CO-4:	Study on FDTD method for photonics band gap	
CO-5:	Understanding the recent advance in photonics Devices	

Text Books
1. S. Sujecki, Photonics Modelling and Design, CRC Press, 2015. **2.** K. Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2000.
Reference Books
1. A. Taflove, Computational Electrodynamics: The Finite-Difference Time Domain Method. Norwood, MA: Artech House, 1995.

Semster III Course details

Course Code	Course Name	L – T – P	Credits
AP 624	**Semiconductor Photonics Devices**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about basic concepts semiconductor physics
- To introduce the optical properties and processes in semiconductor
- To enable the students to understand working principle of LED and diodes

Course Content

Units	Syllabus Details	Hrs
Unit I	**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	**9**
Unit II	**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.	**9**
Unit III	**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.	**9**
Unit IV	**Modulation and Switching Devices:** Analog and Digital Modulation of light sources, Franz-Keldysh and Stark-effect based Modulators, QW Electro-absorption modulator.	**9**
Unit V	**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, Coherent detection. CCDs and PICs.	**9**

Course Outcomes	
CO-1	Understand the basics of Semiconductor Physics
CO-2	Interpret all the optical properties and processes in semiconductors
CO-3	Examine the working mechanism of different kinds of LEDs and LASERs
CO-4	Illustrate the implementation of Modulation and Switching Devices
CO-5	Explain different types of photodiodes and photodetectors

Text Books

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), 6th Ed., Ch.15-17.

Reference Books

1. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007), Ch.16, 17, and 18.
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.

Course Code	**Course Name**	**L – T – P**	**Credits**
AP 623	**Introduction to Fiber Optics**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about basic concepts of fiber optics communication
- To introduce the working mechanism of fiber optics
- To enable the students to practical application of fiber optics communication

Course Content

Units	Syllabus Details	Hrs
Unit I	**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.	**9**

Unit II	**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	**9**
Unit III	**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	**9**
Unit IV	**Optical Fiber Sensors:** Introduction, Classification and Types of Optical Fiber Sensors, Sensor Modulation techniques, Fiber Bragg Grating Sensors: Principle and Applications.	**9**
Unit V	**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.	**9**

Course Outcomes

CO-1	Understand the basics concepts of Fiber Optic Communication
CO-2	Understand all the sub-components of Fiber Optics
CO-3	Examine the working mechanism of Fiber Optics
CO-4	Illustrate the practical implementation of Fiber Optic Communication
CO-5	Summarize different applications of Fiber Optic Communication

Text Books

4. A.K. Ghatak & K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press 1998
5. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008
6. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998

Reference Books

1. J.P. Dakin & B Culshaw, Optical Fiber Sensors, Vol. 1&2., Artech House 1998
2. K.T.V. Grattan & B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, 1988

Course Code	Course Name	L – T – P	Credits
AP 512	**Advanced Photonics Laboratory**	**0-0-4**	**4**

Course Objectives:

- To impart practical knowledge about basic of fiber optics devices
- To analuyse the diff techniques and device perfomamnces
- To enable the students to understand design of different photonic devices

Course Content

Syllabus Details	Hrs
20. Characterization of Fiber Bragg grating 21. Power budget analysis using Optical Time Domain Reflectometer (OTDR) 22. Study of Time Division Multiplexing of digital signals 23. Study of a Wavelength Division Multiplexing(WDM) in optical fiber link 24. Study of Add/drop multiplexer 25. Study of Bit error rate and Eye pattern analysis 26. Setting up a Free space Laser Communication experiment link 27. Measurement of third order nonlinear optical coefficient using Z-scan 28. Study of Faraday effect 29. Design of a fiber optic sensor 30. Line coding and decoding, voice coding 31. Measurement of insertion loss of an isolator, coupler and multiplexer 32. Beat length measurement in birefringent fibers. 33. Laser Raman Spectroscopy Experiments 34. Holography **Note: Any 12 experiments are mandatory**	120 hrs

Course Outcomes

CO-1	Characterization of Fiber Optics Devices
CO-2	Analyse the optical multiplexing techniques and its device performance
CO-3	Examine the working principle of different electro-optic and magneto-optic effects
CO-4	Illustrate the different beam characterization methods
CO-5	Understand the design of different spectroscopic systems

Course Code	Course Name	L – T – P	Credits
AP 513	**Introduction to Programming**	**0-0-2**	**2**

Course Objectives:

- To impart knowledge about basic concepts of fiber optics communication
- To introduce the working mechanism of fiber optics
- To enable the students to practical application of fiber optics communication

Course Content

Units	Syllabus Details	Hrs
Unit I	Introduction to Python & Simple Numerical Programs Installing Python and Python IDEs, Basic elements of Python, Variables and assignment, branching programs, strings and input, loops, Simple codes, approximate solutions, Floats, Newton–Raphson	60 Hrs Practicals
Unit II	Functions, scoping, and abstraction	

	Functions, Scoping, Using functions to modularize code, Functions as objects,	
Unit III	Structured types and mutability Ranges and iterables,Strings, Tuples, Ranges, and Lists, SETS, Dictionaries	
Unit IV	Recursion, global variables, modules and files, classes Fibonacci Numbers, Palindromes, Global Variables, modules, files, testing and debugging, Abstract data types and classes, some important complexity classes	
Unit V	Object-oriented programming, algorithms, data structures, Plotting Search algorithms, sorting algorithms, Matplotlib	

Course Outcomes

CO-1	Learn a language, Python, for expressing computations
CO-2	Develop an informal understanding of computational complexity
CO-3	Examine the process of moving from an ambiguous problem statement to a computational formulation of a method for solving the problem
CO-4	Illustrate the useful set of algorithmic and problem reduction techniques
CO-5	Use computational tools (including simple statistical, visualization, and machine learning tools) to model and understand data

Text Books

3. Introduction to Computation and Programming Using Python, by John V Guttag, MIT Press

Reference Books

Course Code	Course Name	L – T – P	Credits
EE 602	**Digital Signal Processing**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about basic concepts of fiber optics communication
- To introduce the working mechanism of fiber optics
- To enable the students to practical application of fiber optics communication

Course Content

Units	Syllabus Details
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, Eigen values and Eigen vectors, diagonalization, orthogonal diagonalization of symmetric matrices, singular value decomposition.

	Signals: classification of signals, continuous and discrete time signals, sampling theorem, sampling and reconstruction of continuous time signals, baseband and bandpass sampling, complex signal. **Systems:** LTI system, system properties, impulse response and system functions, FIR and IIR systems, convolution and correlation, linear convolution and circular convolution.
Unit II	**PROBABILITY, RANDOM VARIABLE AND RANDOM PROCESS** Randomness, axioms of probability, repeated trails, random variable, distribution and density function, conditional distribution and density, moments, characteristic function, one random variable, two random variable, correlation,covariance, independence, orthogonality, statistics, 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, Markov Chain.
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. **(Design and implementation of all techniques and algorithms studied in this course).**
Unit IV	**TRANSFORMS 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, overlap-add and overlap-save method.
Unit V	**FILTERS Filters:** analog and digital filters, FIR filter design, IIR filter design, and realization using direct, cascade and parallel forms, lattice structures.

LIST OF EXPERIMENTS:

Sl. No	**Experiment**
1.	Introduction of Matlab/Simulink, Labview and its tool boxes
2.	Sampling and Reconstruction of signals
3.	Deterministic & Random Signal analysis using power spectral estimation techniques Period gram power spectral estimation technique PSD through correlogram technique 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 Outcomes

CO-1	Learn the basics of linear algebra, signal, and system.
CO-2	Gain the theory of random variable, probability, and random process.
CO-3	Acquire the basics of transforms such as Fourier transform, Laplace transform, and Hilbert transform
CO-4	Learn the concept of Analog and digital filters

Text 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.

Reference Books

.1. Alan V Oppenheim & Ronald W Schaffer, Discrete Time Signal Processing, PHI.
2. Athanasios Papoulis, Probability, Random Variables, and Stochastic Processes, TATA McGraw Hill

Course Code	Course Name	L-T-P	Credits
EE 624	**Digital system design using FPGA**	**2-0-2**	**4**

Course Objectives:

- To impart knowledge of circuit design techniques.
- To introduce the IIVHDL basics and test pattern generation of algorithms
- To enable the students to understand design of communication modules.

Course Contents

Units	Syllabus Details	Hrs
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.	12

Unit II:	**IIVHDL basics and computation module designs:** Introduction to VHDL - Behavioural modelling - Data flow modelling - Structural modelling - 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.	6
Unit III	**Fault modelling, detection and test pattern generation algorithms:** Introduction to testing – Faults in Digital Circuits – Modelling 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.	6
Unit IV	**Digital system design with real-time I/O interface:** Sensor's 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 - relay/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	1 2
Unit V	**Contemporary designs and solutions:** Design of data path components, Control path components - Design of a simple RISC CPU - Debugging using Embedded Logic Analysers - 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.	1 0

LIST OF EXPERIMENTS:

SL No	NAME OF EXPERIMENTS
01.	The Basic FPGA Design Flow 4. To understand use of Xilinx ISE 5. To understand Xilinx Synthesis Technology or XST. 6. Familiarization of Xilinx Vivado Design Tools.
02.	Familiarization of FPGA Boards 3. Xilinx FPGA Boards (Virtex 6, Kintex7) 4. Implementation of Full adder, ALU, Memory and FIFO on FPGA
03.	Fault Detection Logic Implementation on FPGA 1. Stuck at Fault 2. Memory BIST
04.	Implementation of RISC CPU on FPGA and debugging using Embedded Logic Analysers.

Course Outcomes

CO-1:	Familiarized with the design of Combinational and Synchronous and Asynchronous Sequential Circuits. Gave an Overview of PLDs and PALs
CO-2:	Covered basic introduction of VHDL and the basic language elements. Various Combinational and Sequential circuits were designed using VHDL
CO-3:	In-depth analysis of Faults and testability in digital systems including modelling and detection
CO-4:	Interfacing various sensors and reading/writing to/from various file formats. Implementing various modulation schemes
CO-5:	Design of a RISC CPU, data and control path components. Introduction to various floating/fractional/fixed-point arithmetic operations. Implementing Data encryption/Decryption system, Error correction, communication modules, BERT

Text Books

5. Jesse H. Jenkins, "Designing with FPGAs and CPLDs", Prentice Hall, NJ,1994
6. Fundamentals of Logic Design – Charles H. Roth, 5th ed., Cengage Learning.
7. Kevin Skahill, "VHDL for Programmable Logic", Addison -Wesley, 1996
8. Z. Navabi, "VHDL Analysis and Modelling of Digital Systems", McGraw-Hill, 1998

Reference Books

4. Digital Circuits and Logic Design – Samuel C. Lee, PHI
5. Smith, "Application Specific Integrated Circuits", Addison-Wesley, 1997
6. P.K. Lala, "Digital Circuit Testing and Testability", Academic Press, 2002

Course Code	Course Name	L – T – P	Credits
AP 514	**Introduction to Biophotonics**	**3-0-1**	**4**

Course Objectives: This course is a multidisciplinary course offered as an elective for M.Sc. and M.Sc. (Tech) photonics in the 3rd semester only.

- To impart knowledge about basic concepts of biophotonics
- To introduce the various spectroscopy technioques
- To enable the students to analyze and interpreat outcome of bioimaging

Course Content

Units	Syllabus Details	Hrs
Unit I	**Introduction to Biophotonics:** Overview, light-biological matter interaction, applications	**5**
Unit II	**Basics of Biology:** Introductory Concepts, Cellular Structure, Various Types of Cells, Chemical Building Blocks, Interactions Determining Three-Dimensional Structures of Biopolymers, Other Important Cellular Components, Cellular Processes, Protein Classification and Function, Organization of Cells into Tissues, Types of Tissues and Their Functions, Tumors and Cancers	**10**
Unit III	**Bioimaging:** Principles and Techniques: Simple Microscope, Compound Phase Contrast Microscopy, Dark-Field Microscopy, Differential Interference Contrast Microscopy	**10**

	(DIC) Fluorescence Microscopy, Confocal Microscopy, Multiphoton Microscopy, Optical Coherence Tomography, Total Internal Reflection Fluorescence Microscopy, Near-Field Optical Microscopy	
Unit IV	**Fundamentals of Light-Matter Interactions:** Interactions Between Light and a Molecule, Nature of Interactions, Interaction of Light with a Bulk Matter, Fate of Excited State, Various Types of Spectroscopies, Electronic Absorption Spectroscopy, Electronic Luminescence Spectroscopy, Vibrational Spectroscopy, Spectroscopy Utilizing Optical Activity of Chiral Media, Fluorescence Correlation Spectroscopy (FCS)	**10**
Unit V	**Nanotechnology for Biophotonics:** Bionanophotonics, The Interface of Bioscience, Nanotechnology, and Photonics, Semiconductor Quantum Dots for Bioimaging Metallic Nanoparticles and Nanorods for Biosensing	**10**

Course Outcomes

CO-1	Understand the importance of multidisciplinary concepts and biophtonics
CO-2	Understand the Basics of biological matter
CO-3	Apply the knowledge gained in optics for biomaterials research
CO-4	Learn various spectroscopy techniques
CO-5	Analyse and interpret the outcomes of bioimaging and spectroscopy

Text Books

Reference Books

3. Y. Yeh, V. V Krishnan, Introduction to Biophotonics, 2018., https://doi.org/10.1142/9789813235694_0001.

Semster IV Course details

Course Code	Course Name	L-T-P	Credits
AP 608	**Machine Learning techniques for Sensor Data Analytics**	**2-0-2**	**4**

Course Objectives:

- To impart the knowledge of machine learning techniques.
- To introduce the sensor data analytics, ML examples and ML type of learning
- To enable the students to understand & solve issues with machine learning techniques

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Introduction: Role of Machine learning techniques in sensor data analytics, Learning from data, Machine learning examples, Simple model for Machine Learning, Types of learning,	6
Unit II:	Theory of generalization: Feasibility of learning, Hoeffding inequality, complexity of hypothesis set, growth function, VC dimension, Training versus testing	6

Unit III	Supervised Learning: Perceptron, Linear classification, Linear regression, Logistic regression, Neural Network, Backpropagation algorithm, Support Vector Machines, Radial Basis Functions, K-nearest neighbour, Decision Trees, Bayesian Learning, Deep learning, Feature extraction and dimensionality reduction: Curse of dimensionality, Principal Component analysis, Linear discriminant analysis	12
Unit IV	Unsupervised Learning: Clustering, K-means clustering, hierarchical clustering	10
Unit V	Machine Learning issues: Overfitting, Validation, Occam's razor, Agglomerative Sampling bias, Data Snooping	10

Course Outcomes

CO-1:	Interpret the concepts machine learning
CO-2:	Analyze different types of machine learning techniques
CO-3:	Examine situations where supervised learning can be used
CO-4:	Illustrate implementation of supervised and unsupervised learning.
CO-5:	Summarize different applications of machine learning techniques in sensors

Text Books

4. Thomas A. Runkler, "Data Analytics: Models and Algorithms for Intelligent Data Analysis", Springer Vieweg,2012.
5. S. Haykin, "Neural Networks, A Comprehensive Foundation ", Pearson Education Inc.,2004.
6. Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification, 2nd Edition,2001

Reference Books

5. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer,2006.
6. Y. S. Abu-Mostafa, M. Magdon-Ismail, and Hsuan-Tien Lin, Learning from data, AMLbook.com
7. Y. S. Abu-Mostafa, Learning from data, Caltech lectures(online),
8. S. Sarkar, Introduction to Machine Learning, NPTEL course, IIT Kharagpur(online).

Course Code	Course Name	L-T-P	Credits
AP 642	**Terahertz Devices and Applications**	**3-0-1**	**4**

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 Contents

Units	Syllabus Details	Hrs
Unit I:	**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	**9**
Unit II:	**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;	**9**

	Terahertz sources based on optoelectronics: Photomixer, photoconductive antenna and its types; Noises at terahertz frequencies in different sources	
Unit III	**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	**9**
Unit IV	**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.	**9**
Unit V	**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	**9**

Course Outcomes

CO-1:	Interpret the concepts of terahertz technology
CO-2:	Analyze the working principle of different types of terahertz signal sources
CO-3:	Examine the working mechanism of different types of terahertz detectors
CO-4:	Illustrate the practical implementation of fabrication of components and circuits for terahertz systems
CO-5:	Summarize different applications of terahertz technology for imaging, sensing and communications

Text Books

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 Books

3. H.-J. Song, T. Nagatsuma, Handbook of Terahertz Technologies, Devices and applications, Pan Stanford Publishing Pte. Ltd., 2015.
4. D. Saeedkia, Handbook of Terahertz Technology for Imaging, Sensing and Communications, Woodhead Publishing, 2013.

Course Code	Course Name	L-T-P	Credit

			s
AP 643	**Free Space Optical Communications**	**3-0-1**	**4**

Course Objectives:

- To impart basic knowledge of FSOC
- To introduce the basic techniques of Modelling, Mitigation techniques, Laser beam Tracking, pointing & acquisition.
- To enable the students to understand different application of FSOC.

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**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.	**9**
Unit II:	**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**
Unit III	**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**
Unit IV	**Mitigation techniques:** introduction, aperture averaging, various diversity techniques, spatial diversity, time diversity coding techniques, adaptive optics and other techniques.	**9**
Unit V	**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**

Course Outcomes

CO-1:	Interpret the concepts of Free Space Optical Communication
CO-2:	Understand all the sub-components
CO-3:	Examine the working mechanism of FSOC
CO-4:	Illustrate the practical implementation of FSOC
CO-5:	Summarize different applications of FSOC such as VLC/UWOC

Text Books

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 Books

1. Morris Katzman, Laser Satellite Communications. Prentice Hall Inc 1991
2. Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, A.K. Jha

Course Code	Course Name	L-T-P	Credits
QT 622	**Nonlinear and Quantum Optics**	**3-0-1**	**4**

Course Objectives:

- To impart basic knowledge of nonlinear optics
- To introduce the basic techniques of Modelling, Mitigation techniques, Laser beam Tracking, pointing & acquisition.
- To enable the students to understand different application of FSOC.

Course Contents

Units	Syllabus Details
Unit I:	**Nonlinear optics:** Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients. Second harmonic generation, 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), Third harmonic generation, four wave mixing and Self phase-modulation Optical Kerr effect, Self-focusing, Optical bistability, Stimulated Raman Scattering and Stimulated Brilluoin Scattering, Introduction to ultrashort pulses, Ultrashort pulse generation through mode-locking, Supercontinuum generation
Unit II:	**Quantum Optics:** Field quantization, Correlation functions, photon statistics, shot noise of the photodetectors, Poissonian and sub-Poissonain light, Photon bunching and antibunching, HBT experiment, single photon sources, Coherent states and squeezed states, Phasor diagram, generation and detection of squeezed light, Quantum noise, Phase space representation and Wigner function.

Course Outcomes

CO-1:	Understand basic of Nonlinear optics
CO-2:	Understand the mode polarization
CO-3:	Application of non-liear optics
CO-4:	To understand phase modulation , ultrashort pulses
CO-5:	To know the quantum optics

Text Books

1. R. W. Boyd, Nonlinear Optics, Academic Press, 2008
2. Peter E. Powers, Fundamentals of Nonlinear Optics, CRC Press, 2011.

Reference Books

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

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. The syllabus has been designed as per the guidelines of NEP 2020.

Stakeholders:

(vii) Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments

(viii) 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. Course syllabus is updated periodically to keep pace with the contemporary technological advancement.

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: 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's program

PO4: Having adaptive thinking and adaptability in relation to environmental context and sustainable development

PO5: Having a clear understanding of professional and ethical responsibility

PO6: Having a good cognitive load management skill related to project management and finance

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Sc. (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.

Credit Structure (As per NEP 2020)

1 credit = 15 clock hours of teaching or tutorial

1 credit = 30 clock hours of practica

SEMESTER I

Sl. No.	Course Code	Course	Credit distrubution			Total Credits
			L	T	P	
1	AP 501	Quantum Mechanics	3	1		4
2	AP 502	Introduction to Optics & Photonics	3		1	4
3	AP 503	Introduction to Lasers	3		1	4
4	RM 501	Research Methodology	3	1		4
5	AP 505	Basic Photonics Laboratory	0		2	2
6		Elective 1	3	1		4
		Total	**15**	**03**	**4**	**22**

Options for Elective 1:

Choose Any one						
1	MS 505	Computational Mathematics	3	1		4
2	AM 607	Mathematics of Engineers	3	1		4

SEMESTER II

Sl. No.	Course Code	Course	Credit distribution			Total Credits
			L	T	P	
1	AP 506	Electronic devices and circuits	3		1	4
2	AP 507	Solid State Physics	3	1		4

3	OJT/FP	On-Job Training/Field Project				**4**
4	AP 509	Nanophotonics	3	1		4
5	AP 510	Electronics and Photonics Laboratory	0		2	2
6		Elective 2	3	1		4
		Total	**12**	**03**	**03**	**22**

*** To be completed during the summer vacation (120 Hrs)**

Options for Elective 2:

Choose Any one						
1	AP 631	Laser Applications	3	1		4
2	**AP 508**	Computational Photonics	3	1		4

SEMESTER III

Sl. No.	Course Code	Course	Credit distribution			Total Credits
			L	T	P	
1	AP 624	Semiconductor Photonic devices	3	1		4
2	AP 623	Introduction to Fiber Optics	3	1		4
3	AP 512	Advanced Photonics Laboratory	0		4	4
4	AP 513	Introduction to Programming	0		2	2
5	RP 541	Research Project – 1				**4**
6		Elective 3	3	1		4
		Total	**08**	**02**	**08**	**22**

Options for Elective 3:

Choose Any one						
1	EE 602	Digital Signal processing	3	1		4
2	EE 624	Digital System Design using FPGA	2		2	4
3	AP 514	Introdution ot Biophtonoics	3		1	4

SEMESTER IV

Sl. No.	Course Code	Course	Contact Hours /week			Credits
			L	T	P	
1	AP 608	Machine learning techniques for sensor data analytics	3	1		4
2	AP-642	Tera Hertz Devices and Applications	3	1		4
3	AP 643	Free Space Optical Communication	3	1		4
4	RP 542	Research Project – II				**6**
5		Elective 4	3	1		4
		Total	**12**	**4**		**22**

Options for Elective 4:

Choose Any one						
1	QT 622	Nonlinear and Quantum Optics	3	1		4
2		NPTEL/MOOC course	3	1		4

SEMESTER V

Sl. No.	Course Code	Course	Total Credits
1	AP 551	Major Project Phase - I	20
		Total	**20**

SEMESTER VI

Sl. No.	Course Code	Course	Total Credits
1	AP 552	Major Project Phase - II	20
		Total	**20**

UGC recommended courses (Additional 10 credits)

(to be completed by the student/candidate before the completion of the program)

Cyber Security/Information security - 4 credits

Human Rights-I - 1 credit

Human Rights-II - 1 credit

Introduction to Indian Constitution - 2 credits

Skill Development Courses - 2 credits

Semster I Course details

Course Code	Course Name	L – T – P	Credits
AP 501	**Quantum Mechanics**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about formulation in quantum mechanic physics.
- To introduce the fundamental concepts of quantum mechanic physics.
- To enable the students to underrstand quantum mechanics in lasers.

Course Content

Units	Syllabus Details	Hrs
Unit I	Historical Origin of Quantum mechanics: Thermal radiation, Plank's postulates, Black body radiation, stationary states, correspondence principle, Bohr Atom, shortcomings of old quantum theory.	**9**

Unit II	The Schrödinger equation, Statistical interpretation, probability, normalization, momentum, The uncertainty principle	**6**
Unit III	Time Independent Schrödinger: stationary states, infinite square well, harmonic oscillator, free particle, delta function potential, finite square well	**9**
Unit IV	Formalism: Hilbert's space, observables, eigen function of Hermitian operator, statistical interpretation, Dirac notation	**6**
Unit V	One electron atoms: solution of Schrödinger equation in 3D, eigen values, quantum numbers, and degeneracy, orbital angular	8
Unit VI	Quantum statistics: indistinguishability and quantum statistics, quantum distribution functions, Boltzmann distribution as an approximation to quantum distributions, Introduction to Quantum Optics, Coherent States	**7**

Course Outcomes

CO-1	Understand the basic concepts of quantum mechanics Physics
CO-2	Interpret the physical meaning of formulation in quantum mechanics
CO-3	Examine different 1D problems in quantum mechanics
CO-4	Illustrate the implementation to 1 electron atoms
CO-5	Explain Quantum mechanics to Lasers

Text Books

4. Quantum Mechanics, John Powell, Bernd Crasemann, Narosa Publishing House
5. Quantum Mechanics, Leonard Schiff, Mc-Graw Hill Book Company
6. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing

Reference Books

3. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing
4. Quantum Mechanics by B H Bransden and C J Joachain Pearson Publishing

Course Code	**Course Name**	**L – T – P**	**Credits**
AP 502	**Introduction to Optics and Photonics**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge about formulation in quantum mechanic physics.
- To introduce the fundamental concepts of quantum mechanic physics.
- To enable the students to underrstand quantum mechanics in lasers.

Course Content

Units	Syllabus Details	Hrs
Unit I	**Fundamentals of Photonics and Optics:** Wave equation, Plane waves, Applications of photonics, Reflection and Refraction of plane waves, Fresnel Equations, Wave propagation in different mediums, propagation of Electromagnetic waves in Uniaxial and biaxial crystals, the dielectric constant tensor and the 'index ellipsoid'	**9**
Unit II	**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: polarizing and non-polarizing, wavelength filters, dichroic mirrors, Lenses.	**10**
Unit III	**Electro-optics:** Basic principles: Pockel and Kerr effects, Electro-optic devices: modulators, switches, and scanners, E.O. effect in liquid crystals; LCDs and SLMs, Applications.	**9**
Unit IV	**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 acoustooptictunable filters.	**9**
Unit V	**Magneto-optics**: Principles, Faraday effect, Gyrotropic permittivity, Kerr rotation and Kerr ellipticity, Applications.	8

Course Outcomes

CO-1	Interpret the concepts of optical electronics
CO-2	Analyze the working principle of ME Theory, EO, MO and AO effects
CO-3	Examine the working mechanism of different types of Optical components, EO, MO and AO effects
CO-4	Illustrate the practical use of Optical components, EO, MO and AO effects
CO-5	Summarize different applications of optical electronics devices

Text Books

8. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press,1989. References
9. A. Yariv, P. Yeh, Photonics: Optical Electronics in Modern Communications, The Oxford Series in Electrical and Computer Engineering, 2006.
10. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
11. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000.

Reference Books

4. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
5. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988.
6. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.

Course Code	Course Name	L – T – P	Credits
AP 503	**Introduction to Lasers**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge about laser technology
- To introduce the fundamental concepts of lasers.
- To enable the students to understand working principle of laser systems

Course Content

Units	Syllabus Details	Hrs
Unit I	**Light-matter interaction:** Interaction of radiation with atomic systems, Einstein's coefficients, spontaneous emission, stimulated emission, Linewidth of the laser	10
Unit II	**Lasers Oscillation**: Theory of laser oscillation; Threshold condition, Rate equation, Optical amplification and feedback, Condition for laser oscillation, Characteristics of laser output power, Pumping techniques.	10
Unit III	**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.	10
Unit IV	**Laser Systems 1:** Solid-state lasers, Gas lasers,	8
Unit V	**Laser Systems 2:** Fiber laser and amplifiers	7

Course Outcomes

CO-1	Interpret the concepts of laser technology
CO-2	Analyze the working principle of lasers
CO-3	Examine the laser radiation beams
CO-4	Illustrate and construct the practical laser systems
CO-5	Summarize different types of laser systems and its working principals

Text Books

7. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.
8. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
9. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988

Reference Books

3. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
4. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).

Course Code	Course Name	L – T – P	Credits
AP 505	**Basic Photonics Laboratory**	**0-0-2**	**2**

Course Objectives:

- To impart practical knowledge about basic electronics
- To introduce the charatceristics of devices
- To enable the students to understand working of optical components

Course Content

Syllabus Details	Hrs
Photonics 16. Measurement of Refractive index using Michelson Interferometer 17. Determination of the Electrical and Optical Characteristics of LED and Laser diode. 18. Experiment on Laser beam cleaning by Spatial Filtering 19. Beam Collimation with different telescopic arrangement 20. Measurement of diameter of thin wire using the laser light diffraction method. 21. Young's Single-slit and Double Slit experiment 22. Determine the lines per inch of a Transmission diffraction grating by its dispersive angles. 23. Detection of polarisation states using polarisation components like polarizers, waveplates etc. 24. Analysis of various light source spectra using OSA. 25. Determination of Numerical Aperture and V Number of single mode & multimode fiber. 26. Macro and Microbending loss in optical fibers and its application 27. Measurement of Photodiode characteristics 28. Study of Fraunhofer diffraction pattern of a rectangular and circular aperture. 29. Finding the Verdot's constant by Faraday Effect 30. OptiSystem training module for Optical System Designing	60

Course Outcomes

CO-1	To understand basic electronics
CO-2	To interprete characteristics of the devices
CO-3	Examine the working of basic electronic components
CO-4	Illustrate working of optical components
CO-5	Explain difference in diode and Laser characteristics

Course Code	Course Name	L – T – P	Credits
MS 505	**Computational Mathematics**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge about basic mathematics algebra
- To introduce the concept of scientific computations
- To enable the students to use numerical methods to solve differential equations

Course Content

Units	Syllabus Details	Hrs
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.	**9**
Unit II	Calculus of single and multiple variables: Limit, Continuity and differentiability; Maxima and minima – Necessary and sufficient conditions; Partial derivatives; Total derivative	**9**
Unit III	Vector Calculus: Vector Fields; Gradient, divergence and curl; Line integrals, and Green's theorem; Divergence theorem; Physical interpretation of mathematical operations	**9**
Unit IV	Scientific Computing: Concepts of discretization in space/time, implicit, explicit; Taylor's series; Solution to ODEs	**9**
Unit V	Numerical Solution of Differential Equations: Classification of second order linear partial differential equations; Method of separation of variables: One dimensional heat equation and two-dimensional Laplace equation.	**9**

Course Outcomes

CO-1	Understand the basics of Linear Algebra
CO-2	Recognize the principles of Multivariable calculus
CO-3	Apply the principles of Differential and Integral calculus
CO-4	Interpret the concepts of Scientific Computations
CO-5	Implementing numerical methods to solve differential equations

Text Books

- Advanced engineering mathematics: Kreyszig; Wiley.
- Advanced engineering mathematics: Jain/Iyenger; Narosa

Reference Books
• 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

Semster II Course details

Course Code	**Course Name**	**L – T – P**	**Credits**
AP 506	**Electronic Devices and Circuits**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge about basic of semiconductor
- To introduce the concept of s diodes, transistors and oscillators
- To enable the students to undertand working principles of devices

Course Content

Units	**Syllabus Details**	**Hrs**
Unit I	Basics of semiconductor and Introduction to Diodes: The energy band theory of crystals, Intrinsic and Extrinsic semiconductors. P-N Junction diode as a Rectifier, Photo-Diode, Filters using Diode, Clipping & clamping circuits, LED, Zener diode	8
Unit II	Transistors and Oscillators: Basics of Transistor, Transistor characteristics and applications, basics of oscillators and multivibrators (IC555 as timer).	10
Unit III	Field Effect Transistor: Structure and working of: JFET, I-V characteristics and parameters (Pinch off voltage, trans conductance, drain resistance, amplification factor); MOSFET (construction and application only) Applications: FET as Voltage Variable resistance (VVR), switch, memory cell, DRAM	10
Unit IV	OPAMPS & Multivibrators : Idea op-amplifier characteristics, Block diagram, Basic Inverting & non inverting amplifier, Basics of oscillator, Basics of Timer IC 555 as astable multivibrator.	10
Unit V	Sequential circuits and Counters:	7

	RS, Clocked RS, JK, Master Slave JK, D Flip flop, Counter-synchronous, asynchronous, up-down counter, modulo-N counter, Decade counter (IC 7490); shift register (IC 7495), ring counter	

Course Outcomes

CO-1	Understand the basics of Semiconductos and Diodes
CO-2	Recognize the principles of Transistoirs ans oscillators
CO-3	principles of Field effet transistor
CO-4	Interpret the concepts of OPAMPS & Multivibrators
CO-5	Implementing circuits in devices

Text Books

3. Millman's Integrated Electronics - Analog and Digital Circuit and Systems | 2nd Edition by Jacob Millman, Christos Halkias, Chetan Parikh
4. Electronic Principles | 7th Edition by Albert Malvino , David J. Bates

Reference Books

2. Roberts L Boylestad & Louis Nashelsky Electronic Devices Circuit Theory

Course Code	Course Name	L – T – P	Credits
AP 507	**Solid State Physics**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about basic concepts of solid state physics
- To introduce the electronic and magnetic properties of solid state physics
- To enable the students to solve physics problems

Course Content

Units	Syllabus Details	Hrs
Unit I	**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 dislocations.	8
Unit II	**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.	10
Unit III	**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	10

	theorem. Crystal momentum. Qualitative distinction between semiconductors and metals. Fermi surface of metals. Hall effect.	
Unit IV	**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.	10
Unit V	**Magnetism** – Diamagnetism, Langevin equation. Pauli paramagnetism in metals. Paramagnetism –Curie law. Ferromagnetism. Quantum mechanical nature of ferromagnetic interaction. Anti-ferromagnetic and ferromagnetic order.	7

Course Outcomes

CO-1	Understand the basic concepts of Solid State Physics
CO-2	Interpret the physical meaning of formulation in Condensed Mateer
CO-3	Examine different Structure related properties
CO-4	Study the Electronic and magnetic properties of solids
CO-5	Develop skills to solve physics problems

Text Books

1. Introduction to Solid State Physics, Charles Kittel (John Wiley and Sons.).

2. Solid State Physics, A. J. Dekkar (Prentice Hall).

Reference Books

1. Solid State Physics, N. W. Ashcroft and N. D. Mermin (CBS Publishing Asia Ltd.).

Course Code	Course Name	L – T – P	Credits
AP 509	**Nanophotonics**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about basic concepts of solid state physics
- To introduce the electronic and magnetic properties of solid state physics
- To enable the students to solve physics problems

Course Content

Units	Syllabus Details	Hrs
Unit I	Basics of Nanophotonics: Photons and electrons, Quantum confinement effects, 2D, 1D, 0D structures, their growth and properties	**9**
Unit II	**Metamaterials:** Definition of Metamaterials (MTMs) and Left-Handed (LH) MTMs, **Fundamentals of LH MTMs** Left-Handedness from Maxwell's Equations	**9**

Unit III	**Metamaterial in Optics:** Optical Properties of Metal-Dielectric Composites, Optical Magnetism, Negative-refractive Index, Perfect lens and Cloaking objects.	**9**
Unit IV	**Surface Plasmon Resonance:** Evanescent waves, Surface Plasmon dispersion equations, resonance, excitation od surface plsmons, surface Plasmon properties, SPR spectroscopy	**9**
Unit V	**Photonic band gap crystals:** Photonics Band-Gap: Introduction to Photonics crystal, Photonic Band Structures, One dimensional, Photonic crystal: Origin of Photonics Band Gap, Size of the band gap, Evanescent Modes in Photonics Band gaps, Two-dimensional Photonic crystal: Two-dimensional Bloch States, Square Lattices (Dielectric Columns and Veins), Three-dimensional Photonic crystal: Three-dimensional lattices,	**11**

Course Outcomes

CO-1	Familiarization to the concept of Metamaterials
CO-2	Illustration of Optical Properties in Metamaterials
CO-3	Examine Surface Plasmon Resonance
CO-4	Analyze Photonic Bandgap Crystals in different dimensions
CO-5	Understanding the Importance of Silicon Photonics and Its Applications

Text Books

8. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, Christophe Caloz,Tatsuo Itoh, John Wiley and Sons,2006
9. Optical Metamaterials, Fundamentals and Applications, Wenshan Cai Vladimir Shalaev, Springer, 2010.
10.John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, and Robert D. Meade,Photonic Crystal: Molding Light Flow of Light, Princeton University Press, 2008.

Reference Books

4. Graham T. Reed and Andrew P. Knights, Silicon Photonics: An Introduction, JohnWiley and Sons Ltd, 2004
5. Metamaterials: Physics and Engineering Explorations, Nader Engheta Richard W. Ziolkowski, Wiley and Sons,2006
6. Negative-Refraction Metamaterials Fundamental Principles and Applications, G. I. Eleftheriades K. G. Balmain,Wiley and Sons,2005

Course Code	Course Name	L – T – P	Credits
AP 510	**Electronics and Photonics Laboratory**	**0-0-2**	**2**

Course Objectives:

- To impart practical knowledge about basic logic circuits
- To introduce the working of holography
- To enable the students to understand working of fiber optical communication

Course Content

Syllabus Details	**Hrs**
Electronics: 10. To study the I-V Characteristics of Diodes (Simple and Zener Diode)	60 hrs

11. To study the I-V Characteristics of Transistors in CB, CE, CC modes (NPN and PNP Transistors)
12. To study the I-V Characteristics of MOSFETs
13. To study the Half, Full, and Bridge rectifier
14. To study the Voltage and Current regulation with a fixed load
15. To study the Clipping and clamping Circuit
16. To study the Characteristics of 741 OPAMPs
17. To analyze the inverting and non-inverting amplifier
18. To Design Active filters

Photonics:

9. Beam Width, Divergence, and M^2 measurement of He-Ne/Diode Laser with and without collimation lens.
10. Fiber optic link design
11. Measurement of attenuation and dispersion in optical fibers
12. Fiber to Fiber splicing (SM-SM, SM-MM, MM-MM, PM, etc.) and splicing loss measurement.
13. Setting up of Mach-Zender interferometer
14. Design of driver circuit for LED and Laser diode
15. Characterization of Erbium Doped Fiber Amplifier
16. Simulation of Basic FBG Fiber Loop Mirror Sensor Designing using Optiwave softwave Design of signal conditioning circuits for Photodetectors

Course Outcomes

CO-1	Understand basic logic circuits
CO-2	Analyze the working of A/D and D/A convertors
CO-3	Illustrate the working Holography
CO-4	Examine the losses in fiber optical communication
CO-5	Interprete the working of fiber lasers

Course Code	Course Name	L-T-P	Credits
AP 631	**Laser Applications**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Laser applications.
- To introduces the Holography, Laser Metrology and Laser Spectroscopy
- To enable the students to understand Industrial and defence applications

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**Laser Metrology: Laser** for measurement of distance, length, velocity, acceleration; rotation sensing; RLG and FOG.	**6**
Unit II:	**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**
Unit III	**Holography:** Holographic interferometry and applications; Holography for non – destructive testing – Holographic components	**6**

Unit IV	**Industrial Application of Laser:** Laser cutting, Laser welding, Laser drilling, Laser marking, Photolithography, Laser-based unmanned ground vehicles	**9**
Unit V	**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	**12**

Course Outcomes

CO-1:	Familiarize to a variety of applications on lasers
CO-2:	Interpret how laser-based metrological techniques work
CO-3:	Understand laser spectroscopy applications
CO-4:	Investigate various methods of how a laser can be used for defence applications
CO-5:	Summarize different applications of lasers

Text Books

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 Books

1. K. Bharat, Laser Safety Tools and Training, CRC Press 2009
2. K. Nagothu, New Paradigms for Underwater Communication, ProQuest 2009

Course Code	Course Name	L-T-P	Credits
AP 508	**Computational Photonics**	**3-0-1**	**4**

Course Objectives:

- To impart knowledge of Laser applications.
- To introduces the Holography, Laser Metrology and Laser Spectroscopy
- To enable the students to understand Industrial and defence applications

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**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, plasmonic and microwave waveguides,	9
Unit II:	**Beam Propagation Method:** Theory and working of beam propagation method, Tutorials on MMI couplers, optical gratings, co-directional couplers or polarization converters.	9
Unit III	**FDTD Method:** Theory and working of FDTD method, Tutorials on photonics band gap simulation: 2D and 3D of different crystal lattices.	9
Unit IV	**Fiber Optics Modeling:** Simulation and modeling of single mode and multimode optical fiber using mode solver, FBG and Chirped FBG synthesis, photonic crystal fiber simulation	8
Unit V	**Nanodesign:** Mask designing for nanofabrication of different device geometry	7
Unit VI	**Introduction to Finite Element Method**	3

Course Outcomes

CO-1:	Understand the simulation methos of photonics devices and fiber Optics
CO-2:	Study on mode solution method of photonics devices
CO-3:	Study on beam propagation method for Photonics devices
CO-4:	Study on FDTD method for photonics band gap
CO-5:	Understanding the recent advance in photonics Devices

Text Books

3. S. Sujecki, Photonics Modelling and Design, CRC Press, 2015.
4. K. Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2000.

Reference Books

2. A. Taflove, Computational Electrodynamics: The Finite-Difference Time Domain Method. Norwood, MA: Artech House, 1995.

Semster III Course details

Course Code	Course Name	L – T – P	Credits
AP 624	**Semiconductor Photonics Devices**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about basic concepts semiconductor physics
- To introduce the optical properties and processes in semiconductor
- To enable the students to understand working principle of LED and diodes

Course Content

Units	Syllabus Details	Hrs
Unit I	**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	**9**
Unit II	**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.	**9**
Unit III	**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.	**9**
Unit IV	**Modulation and Switching Devices:** Analog and Digital Modulation of light sources, Franz-Keldysh and Stark-effect based Modulators, QW Electro-absorption modulator.	**9**

Unit V	**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, Coherent detection. CCDs and PICs.	**9**

Course Outcomes

CO-1	Understand the basics of Semiconductor Physics
CO-2	Interpret all the optical properties and processes in semiconductors
CO-3	Examine the working mechanism of different kinds of LEDs and LASERs
CO-4	Illustrate the implementation of Modulation and Switching Devices
CO-5	Explain different types of photodiodes and photodetectors

Text Books

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), 6th Ed., Ch.15-17.

Reference Books

4. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007), Ch.16, 17, and 18.
5. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021).
6. Streetman, Ben, and Sanjay Banerjee. Solid state electronic devices. Pearson Higher Ed, 2015.

Course Code	Course Name	L – T – P	Credits
AP 623	**Introduction to Fiber Optics**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about basic concepts of fiber optics communication
- To introduce the working mechanism of fiber optics
- To enable the students to practical application of fiber optics communication

Course Content

Units	Syllabus Details	Hrs
Unit I	**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.	**9**
Unit II	**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.	**9**

	Optical Receivers: Basic Concepts, Common Photodetectors, Receiver Design, Receiver Noise, Coherent Detection, Receiver Sensitivity, Sensitivity Degradation, Receiver bandwidth, and Performance	
Unit III	**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	**9**
Unit IV	**Optical Fiber Sensors:** Introduction, Classification and Types of Optical Fiber Sensors, Sensor Modulation techniques, Fiber Bragg Grating Sensors: Principle and Applications.	**9**
Unit V	**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.	**9**

Course Outcomes

CO-1	Understand the basics concepts of Fiber Optic Communication
CO-2	Understand all the sub-components of Fiber Optics
CO-3	Examine the working mechanism of Fiber Optics
CO-4	Illustrate the practical implementation of Fiber Optic Communication
CO-5	Summarize different applications of Fiber Optic Communication

Text Books

7. A.K. Ghatak & K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press 1998
8. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008
9. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998

Reference Books

3. J.P. Dakin & B Culshaw, Optical Fiber Sensors, Vol. 1&2., Artech House 1998
4. K.T.V. Grattan & B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, 1988

Course Code	**Course Name**	**L – T – P**	**Credits**
AP 512	**Advanced Photonics Laboratory**	**0-0-4**	**4**

Course Objectives:

- To impart practical knowledge about basic of fiber optics devices
- To analuyse the diff techniques and device perfomamnces
- To enable the students to understand design of different photonic devices

Course Content

Syllabus Details	**Hrs**
35. Characterization of Fiber Bragg grating 36. Power budget analysis using Optical Time Domain Reflectometer (OTDR) 37. Study of Time Division Multiplexing of digital signals	120 hrs

38.	Study of a Wavelength Division Multiplexing(WDM) in optical fiber link	
39.	Study of Add/drop multiplexer	
40.	Study of Bit error rate and Eye pattern analysis	
41.	Setting up a Free space Laser Communication experiment link	
42.	Measurement of third order nonlinear optical coefficient using Z-scan	
43.	Study of Faraday effect	
44.	Design of a fiber optic sensor	
45.	Line coding and decoding, voice coding	
46.	Measurement of insertion loss of an isolator, coupler and multiplexer	
47.	Beat length measurement in birefringent fibers.	
48.	Laser Raman Spectroscopy Experiments	
49.	Holography	
	Note: Any 12 experiments are mandatory	

Course Outcomes

CO-1	Characterization of Fiber Optics Devices
CO-2	Analyse the optical multiplexing techniques and its device performance
CO-3	Examine the working principle of different electro-optic and magneto-optic effects
CO-4	Illustrate the different beam characterization methods
CO-5	Understand the design of different spectroscopic systems

Course Code	Course Name	L – T – P	Credits
AP 513	**Introduction to Programming**	**0-0-2**	**2**

Course Objectives:

- To impart knowledge about basic concepts of fiber optics communication
- To introduce the working mechanism of fiber optics
- To enable the students to practical application of fiber optics communication

Course Content

Units	Syllabus Details	Hrs
Unit I	Introduction to Python & Simple Numerical Programs Installing Python and Python IDEs, Basic elements of Python, Variables and assignment, branching programs, strings and input, loops, Simple codes, approximate solutions, Floats, Newton–Raphson	60 Hrs Practicals
Unit II	Functions, scoping, and abstraction Functions, Scoping, Using functions to modularize code, Functions as objects,	
Unit III	Structured types and mutability Ranges and iterables,Strings, Tuples, Ranges, and Lists, SETS, Dictionaries	
Unit IV	Recursion, global variables, modules and files, classes	

	Fibonacci Numbers, Palindromes, Global Variables, modules, files, testing and debugging, Abstract data types and classes, some important complexity classes	
Unit V	Object-oriented programming, algorithms, data structures, Plotting Search algorithms, sorting algorithms, Matplotlib	

Course Outcomes

CO-1	Learn a language, Python, for expressing computations
CO-2	Develop an informal understanding of computational complexity
CO-3	Examine the process of moving from an ambiguous problem statement to a computational formulation of a method for solving the problem
CO-4	Illustrate the useful set of algorithmic and problem reduction techniques
CO-5	Use computational tools (including simple statistical, visualization, and machine learning tools) to model and understand data

Text Books

4. Introduction to Computation and Programming Using Python, by John V Guttag, MIT Press

Reference Books

Course Code	Course Name	L – T – P	Credits
EE 602	**Digital Signal Processing**	**3-1-0**	**4**

Course Objectives:

- To impart knowledge about basic concepts of fiber optics communication
- To introduce the working mechanism of fiber optics
- To enable the students to practical application of fiber optics communication

Course Content

Units	Syllabus Details
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, Eigen values and Eigen vectors, diagonalization, orthogonal diagonalization of symmetric matrices, singular value decomposition. **Signals:** classification of signals, continuous and discrete time signals, sampling theorem, sampling and reconstruction of continuous time signals, baseband and bandpass sampling, complex signal. **Systems:** LTI system, system properties, impulse response and system functions, FIR and IIR systems, convolution and correlation, linear convolution and circular convolution.
Unit II	**PROBABILITY, RANDOM VARIABLE AND RANDOM PROCESS** Randomness, axioms of probability, repeated trails, random variable, distribution and density function, conditional distribution and density, moments, characteristic function, one random

	variable, two random variable, correlation,covariance, independence, orthogonality, statistics, 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, Markov Chain.
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. **(Design and implementation of all techniques and algorithms studied in this course).**
Unit IV	**TRANSFORMS 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, overlap-add and overlap-save method.
Unit V	**FILTERS Filters:** analog and digital filters, FIR filter design, IIR filter design, and realization using direct, cascade and parallel forms, lattice structures.

LIST OF EXPERIMENTS:

Sl. No	**Experiment**
1.	Introduction of Matlab/Simulink, Labview and its tool boxes
2.	Sampling and Reconstruction of signals
3.	Deterministic & Random Signal analysis using power spectral estimation techniques Period gram power spectral estimation technique PSD through correlogram technique 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 Outcomes

CO-1	Learn the basics of linear algebra, signal, and system.
CO-2	Gain the theory of random variable, probability, and random process.
CO-3	Acquire the basics of transforms such as Fourier transform, Laplace transform, and Hilbert transform
CO-4	Learn the concept of Analog and digital filters

Text 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.

Reference Books

.1. Alan V Oppenheim & Ronald W Schaffer, Discrete Time Signal Processing, PHI.
2. Athanasios Papoulis, Probability, Random Variables, and Stochastic Processes, TATA McGraw Hill

Course Code	Course Name	L-T-P	Credits
EE 624	**Digital system design using FPGA**	**2-0-2**	**4**

Course Objectives:

- To impart knowledge of circuit design techniques.
- To introduce the IIVHDL basics and test pattern generation of algorithms
- To enable the students to understand design of communication modules.

Course Contents

Units	Syllabus Details	Hrs
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.	12
Unit II:	**IIVHDL basics and computation module designs:** Introduction to VHDL - Behavioural modelling - Data flow modelling - Structural modelling - 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.	6
Unit III	**Fault modelling, detection and test pattern generation algorithms:** Introduction to testing – Faults in Digital Circuits – Modelling of faults – Logical Fault Models – Fault detection – Fault Location – Fault dominance – Logic simulation – Test	6

	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:** Sensor's 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 - relay/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	12
Unit V	**Contemporary designs and solutions:** Design of data path components, Control path components - Design of a simple RISC CPU - Debugging using Embedded Logic Analysers - 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.	10

LIST OF EXPERIMENTS:

SL No	NAME OF EXPERIMENTS
01.	The Basic FPGA Design Flow 7. To understand use of Xilinx ISE 8. To understand Xilinx Synthesis Technology or XST. 9. Familiarization of Xilinx Vivado Design Tools.
02.	Familiarization of FPGA Boards 5. Xilinx FPGA Boards (Virtex 6, Kintex7) 6. Implementation of Full adder, ALU, Memory and FIFO on FPGA
03.	Fault Detection Logic Implementation on FPGA 1. Stuck at Fault 2. Memory BIST
04.	Implementation of RISC CPU on FPGA and debugging using Embedded Logic Analysers.

Course Outcomes

CO-1:	Familiarized with the design of Combinational and Synchronous and Asynchronous Sequential Circuits. Gave an Overview of PLDs and PALs
CO-2:	Covered basic introduction of VHDL and the basic language elements. Various Combinational and Sequential circuits were designed using VHDL
CO-3:	In-depth analysis of Faults and testability in digital systems including modelling and detection
CO-4:	Interfacing various sensors and reading/writing to/from various file formats. Implementing various modulation schemes
CO-5:	Design of a RISC CPU, data and control path components. Introduction to various floating/fractional/fixed-point arithmetic operations. Implementing Data encryption/Decryption system, Error correction, communication modules, BERT

Text Books

9. Jesse H. Jenkins, "Designing with FPGAs and CPLDs", Prentice Hall, NJ,1994
10. Fundamentals of Logic Design – Charles H. Roth, 5th ed., Cengage Learning.
11. Kevin Skahill, "VHDL for Programmable Logic", Addison -Wesley, 1996
12. Z. Navabi, "VHDL Analysis and Modelling of Digital Systems", McGraw-Hill, 1998

Reference Books
7. Digital Circuits and Logic Design – Samuel C. Lee, PHI 8. Smith, "Application Specific Integrated Circuits", Addison-Wesley, 1997 **9.** P.K. Lala, "Digital Circuit Testing and Testability", Academic Press, 2002

Course Code	Course Name	L – T – P	Credits
AP 514	**Introduction to Biophotonics**	**3-0-1**	**4**

Course Objectives: This course is a multidisciplinary course offered as an elective for M.Sc. and M.Sc. (Tech) photonics in the 3rd semester only.

- To impart knowledge about basic concepts of biophotonics
- To introduce the various spectroscopy technioques
- To enable the students to analyze and interpreat outcome of bioimaging

Course Content

Units	Syllabus Details	Hrs
Unit I	**Introduction to Biophotonics:** Overview, light-biological matter interaction, applications	**5**
Unit II	**Basics of Biology:** Introductory Concepts, Cellular Structure, Various Types of Cells, Chemical Building Blocks, Interactions Determining Three-Dimensional Structures of Biopolymers, Other Important Cellular Components, Cellular Processes, Protein Classification and Function, Organization of Cells into Tissues, Types of Tissues and Their Functions, Tumors and Cancers	**10**
Unit III	**Bioimaging:** Principles and Techniques: Simple Microscope, Compound Phase Contrast Microscopy, Dark-Field Microscopy, Differential Interference Contrast Microscopy (DIC) Fluorescence Microscopy, Confocal Microscopy, Multiphoton Microscopy, Optical Coherence Tomography, Total Internal Reflection Fluorescence Microscopy, Near-Field Optical Microscopy	**10**
Unit IV	**Fundamentals of Light-Matter Interactions:** Interactions Between Light and a Molecule, Nature of Interactions, Interaction of Light with a Bulk Matter, Fate of Excited State, Various Types of Spectroscopies, Electronic Absorption Spectroscopy, Electronic Luminescence Spectroscopy, Vibrational Spectroscopy, Spectroscopy Utilizing Optical Activity of Chiral Media, Fluorescence Correlation Spectroscopy (FCS)	**10**
Unit V	**Nanotechnology for Biophotonics:** Bionanophotonics, The Interface of Bioscience, Nanotechnology, and Photonics, Semiconductor Quantum Dots for Bioimaging Metallic Nanoparticles and Nanorods for Biosensing	**10**

Course Outcomes

CO-1	Understand the importance of multidisciplinary concepts and biophtonics
CO-2	Understand the Basics of biological matter
CO-3	Apply the knowledge gained in optics for biomaterials research
CO-4	Learn various spectroscopy techniques
CO-5	Analyse and interpret the outcomes of bioimaging and spectroscopy

Reference Books

3. Y. Yeh, V. V Krishnan, Introduction to Biophotonics, 2018., https://doi.org/10.1142/9789813235694_0001.

Semster IV Course details

Course Code	Course Name	L-T-P	Credits
AP 608	**Machine Learning techniques for Sensor Data Analytics**	**2-0-2**	**4**

Course Objectives:

- To impart the knowledge of machine learning techniques.
- To introduce the sensor data analytics, ML examples and ML type of learning
- To enable the students to understand & solve issues with machine learning techniques

Course Contents

Units	Syllabus Details	Hrs
Unit I:	Introduction: Role of Machine learning techniques in sensor data analytics, Learning from data, Machine learning examples, Simple model for Machine Learning, Types of learning,	6
Unit II:	Theory of generalization: Feasibility of learning, Hoeffding inequality, complexity of hypothesis set, growth function, VC dimension, Training versus testing	6
Unit III	Supervised Learning: Perceptron, Linear classification, Linear regression, Logistic regression, Neural Network, Backpropagation algorithm, Support Vector Machines, Radial Basis Functions, K-nearest neighbour, Decision Trees, Bayesian Learning, Deep learning, Feature extraction and dimensionality reduction: Curse of dimensionality, Principal Component analysis, Linear discriminant analysis	12
Unit IV	Unsupervised Learning: Clustering, K-means clustering, hierarchical clustering	10
Unit V	Machine Learning issues: Overfitting, Validation, Occam's razor, Agglomerative Sampling bias, Data Snooping	10

Course Outcomes

CO-1:	Interpret the concepts machine learning
CO-2:	Analyze different types of machine learning techniques
CO-3:	Examine situations where supervised learning can be used
CO-4:	Illustrate implementation of supervised and unsupervised learning.
CO-5:	Summarize different applications of machine learning techniques in sensors

Text Books

7. Thomas A. Runkler, "Data Analytics: Models and Algorithms for Intelligent Data Analysis", Springer Vieweg,2012.
8. S. Haykin, "Neural Networks, A Comprehensive Foundation ", Pearson Education Inc.,2004.
9. Richard O. Duda, Peter E. Hart, David G. Stork, Pattern Classification, 2nd Edition,2001

Reference Books

9. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer,2006.

10. Y. S. Abu-Mostafa, M. Magdon-Ismail, and Hsuan-Tien Lin, Learning from data, AMLbook.com
11. Y. S. Abu-Mostafa, Learning from data, Caltech lectures(online),
12. S. Sarkar, Introduction to Machine Learning, NPTEL course, IIT Kharagpur(online).

Course Code	Course Name	L-T-P	Credits
AP 642	**Terahertz Devices and Applications**	**3-0-1**	**4**

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 Contents

Units	Syllabus Details	Hrs
Unit I:	**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	**9**
Unit II:	**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	**9**
Unit III	**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	**9**
Unit IV	**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.	**9**
Unit V	**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	**9**

Course Outcomes

CO-1:	Interpret the concepts of terahertz technology
CO-2:	Analyze the working principle of different types of terahertz signal sources
CO-3:	Examine the working mechanism of different types of terahertz detectors
CO-4:	Illustrate the practical implementation of fabrication of components and circuits for terahertz systems
CO-5:	Summarize different applications of terahertz technology for imaging, sensing and communications

Text Books

7. A. Rostami, H. Rasooli, H. Baghban, Terahertz Technology: Fundamentals and Applications, Germany, Springer, 2011.
8. R. E. Miles, P. Harrison, D. Lippens, Terahertz Sources and Systems “, Dordrecht: Kluwer, Springer, 2000.
9. K. Sakai, Terahertz Optoelectronics, Springer, 2004.

Reference Books

5. H.-J. Song, T. Nagatsuma, Handbook of Terahertz Technologies, Devices and applications, Pan Stanford Publishing Pte. Ltd., 2015.
6. D. Saeedkia, Handbook of Terahertz Technology for Imaging, Sensing and Communications, Woodhead Publishing, 2013.

Course Code	Course Name	L-T-P	Credits
AP 643	**Free Space Optical Communications**	**3-0-1**	**4**

Course Objectives:

- To impart basic knowledge of FSOC
- To introduce the basic techniques of Modelling, Mitigation techniques, Laser beam Tracking, pointing & acquisition.
- To enable the students to understand different application of FSOC.

Course Contents

Units	Syllabus Details	Hrs
Unit I:	**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.	**9**
Unit II:	**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**
Unit III	**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**
Unit IV	**Mitigation techniques:** introduction, aperture averaging, various diversity techniques, spatial diversity, time diversity coding techniques, adaptive optics and other techniques.	**9**
Unit V	**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**

Course Outcomes

CO-1:	Interpret the concepts of Free Space Optical Communication
CO-2:	Understand all the sub-components
CO-3:	Examine the working mechanism of FSOC

CO-4:	Illustrate the practical implementation of FSOC
CO-5:	Summarize different applications of FSOC such as VLC/UWOC

Text Books

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 Books

1. Morris Katzman, Laser Satellite Communications. Prentice Hall Inc 1991
2. Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, A.K. Jha

Course Code	Course Name	L-T-P	Credits
QT 622	**Nonlinear and Quantum Optics**	**3-0-1**	**4**

Course Objectives:

- To impart basic knowledge of nonlinear optics
- To introduce the basic techniques of Modelling, Mitigation techniques, Laser beam Tracking, pointing & acquisition.
- To enable the students to understand different application of FSOC.

Course Contents

Units	Syllabus Details
Unit I:	**Nonlinear optics:** Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients. Second harmonic generation, 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), Third harmonic generation, four wave mixing and Self phase-modulation Optical Kerr effect, Self-focusing, Optical bistability, Stimulated Raman Scattering and Stimulated Brilluoin Scattering, Introduction to ultrashort pulses, Ultrashort pulse generation through mode-locking, Supercontinuum generation
Unit II:	**Quantum Optics:** Field quantization, Correlation functions, photon statistics, shot noise of the photodetectors, Poissonian and sub-Poissonain light, Photon bunching and antibunching, HBT experiment, single photon sources, Coherent states and squeezed states, Phasor diagram, generation and detection of squeezed light, Quantum noise, Phase space representation and Wigner function.

Course Outcomes

CO-1:	Understand basic of Nonlinear optics
CO-2:	Understand the mode polarization
CO-3:	Application of non-liear optics
CO-4:	To understand phase modulation , ultrashort pulses
CO-5:	To know the quantum optics

Text Books

1. R. W. Boyd, Nonlinear Optics, Academic Press, 2008
2. Peter E. Powers, Fundamentals of Nonlinear Optics, CRC Press, 2011.

Reference Books

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

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 dissertation 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.

<u>Organization of M.Sc programme:</u>

This programme is of four-semester duration. The first semester is comprised of four theory courses and two Lab courses 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 and second semester contains all courses as compulsory, while 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 that 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 three 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.

<u>Eligibility Criteria for Admission to join this programme</u>

<table>
<tr><td rowspan="2">M. Sc.
(Data Science)</td><td>Minimum Educational Qualifications:
The candidate must have a qualified Bachelor’s degree in any branch or discipline / BCA / B. Mathematics / B. Statistics.</td></tr>
<tr><td>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).</td></tr>
</table>

<u>Programme objectives and Outcomes.</u>

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			Credit s
			L	T	P	C
8.	AMMSCD 501	Computational Linear Algebra	3	1	0	4
9.	AMMSCD 502	Probability & Statistical Methods with R	3	0	0	3
10.	AMMSCD 503	Data Science with Python	3	0	0	3
11.	AMMSCD 504	Data Science with Python Lab	0	0	4	2
12.	AMMSCD 505	Probability & Statistical Methods with R Lab	0	0	4	2
13.	AMMSCD 506	Data Structures and Algorithms	3	1	0	4
14.	RM 501	Research Methodology	3	1	0	4
		TOTAL	15	03	08	22

Semester II:

Sl. No.	Course Code	Course Name	Contact hours /week			Credits
			L	T	P	C
1.	AMMSCD 521	Optimization Techniques	3	1	0	4
2.	AMMSCD 522	Time Series Analysis & Forecasting Methods	3	1	0	4
3.	AMMSCD 523	Machine Learning and Deep Learning	3	0	0	3
4.	CSMSCD 530	Big Data Analysis and Algorithms	3	1	0	4
5.	AMMSCD 524	Machine Learning and Deep Learning Lab	0	0	4	2
6.	OJT/FP	On-Job Training/Field Project (120 Hrs)	0	0	8	4
		TOTAL	12	03	12	21

Semester III:

Sl. No.	Course Code	Course Name	Contact hours / week			Credits
			L	T	P	C
1.	AMMSCD 531	Regression Analysis and Predictive Modelling	3	1	0	4
2.	CSMSCD 540	Artificial Intelligence	3	1	0	4
3.		Elective - 1 (Data Security)	3	0	0	3
4.		Elective - 2	3	0	0	3
5.		Elective - 3	3	0	0	3
6.	RP 541	Guided Project - I	12**			06
		TOTAL	15	02	12**	23

Semester IV:

Sl. No.	Course Code	Course Name	Contact hours / week		Credits
			L	T / P	
1.	RP 542	Guided Project - II	28**		14
		TOTAL	28		14

****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 6 credits can be earned through NPTEL MOOC courses as elective courses.

Sl. No.	Course Code	Course
1.	AMMSCD 532	Multivariate Data Analysis
2.	AMMSCD 533	Digital Image Processing
3.	AMMSCD 534	Reinforcement Learning
4.	AMMSCD 535	Data Mining Techniques
5.	AMMSCD 536	Mathematical Cryptography
6.	CSMSCD 541	Natural Language Processing
7.	CSMSCD 542	Pattern Recognition
8.	CSMSCD 543	Cloud Computing
9.	CSMSCD 544	Computer Vision
10.	CSMSCD 545	Computer Forensics
11.	CSMSCD 546	IoT Analytics
12.	CSMSCD 547	Distributed Databases
13.	CSMSCD 548	Data Security
14.	CSMSCD 549	Advanced Database Management Systems
15.	CSMSCD 550	Computer Organization and Architecture
16.	CSMSCD 551	Generative AI
17.	CSMSCD 552	Advanced NLP with LLMs
18.	TMMSCD 550	Business Economics and Financial Analysis
19.	SRMSCD 560	Symbolic AI
20.	SRMSCD 561	Data-driven Robotics and Learning Control
21.	MOOC / NPTEL	

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 courses 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) **Guided Project I and II** 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 350 marks (14 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.	**120 Marks (Viva Voce Committee)**

	Summary of the Project Report (As per DIAT-PGC Rules & Regulations) 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 ➢ Testing Technologies used ➢ What contribution would the project make? **TOPIC OF THE PROJECT**- 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. **OBJECTIVE AND SCOPE:** 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. **PROCESS DESCRIPTION:** 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. **RESOURCES AND LIMITATIONS:** 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. **CONCLUSION:** 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**
AMMSCD501	**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 matrixnorms, 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

12. Linear Algebra and Its Applications - by Gilbert Strang, 4th Edition, Thomson Brooks/Cole.
13. Numerical Linear Algebra - by L. N. Trefethen and David Bau, SIAM, 1997.
14. Matrix Analysis and Applied Linear Algebra - by Carl D. Meyer, SIAM, 2000
15. Fundamentals of Matrix Computation - by D. S. Watkins, 2nd Edn Wiley, 2002.

Reference Books

9. Applied Numerical Linear Algebra - by J.W. Demmel, SIAM, 1997.
10. Matrix Computation - by G. H. Golub and C.F.Van Loan, 3rd Edn., Hindustan book agency, 2007.
11. Numerical Linear Algebra and Applications - by B. N. Datta, 2nd Edn., SIAM, 2010.
12. 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 Algbera by Prof. Premananda Bera, IIT Roorkee

Course Code	Course Name	L – T – P	**Credits**
AMMSCD502	**Probability & Statistical Methods with R**	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: Descriptive Statistics
Raw Data – Graphical Plots and Charts - Frequency Distribution – Histogram and Frequency Polygons – Relative Frequency Distributions – Cumulative Frequency Distributions – Frequency Curves and Their Types - Measures of Central Tendency: Mean, Median, Mode, Trimmed Mean – Measures of Dispersion: Range, Standard Deviation, Quartile Deviation, Mean and Median Absolute Deviation – Moments - Measures of Skewness and Kurtosis – Notion of Linear Correlation and Linear Regression – Simple Problems.

Unit – 2: Basic Probability, Random Variables and Probability Distributions
Concept of Probability – Axioms of Probability - Conditional Probability – Simple Problems - Independent Events - Bayes' Rule (without proof) and Simple Applications. Discrete and Continuous Random Variables, Probability Distributions for Discrete and Continuous Random

Variables – Distribution Functions for Discrete and Continuous Random Variables – Joint Distributions - Independent Random Variables - Probability Distributions of Functions of Random Variables – Marginal and Conditional Distributions – Mathematical Expectation.

Unit – 3: Special Probability Distributions
Notions of Binomial, Poisson Distribution and Normal Distributions – Properties – Relationship Between Binomial and Normal Distributions, Poisson and Normal Distributions – Uniform, Exponential, Gamma Distributions, t, Chi-square and F Distributions - Bivariate Normal Distribution – Simulation: Random Number Generation from Exponential, Gamma and Normal Distributions.

Unit – 4: Sampling Theory and Statistical Estimation Theory
The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population,
Sampling Techniques and Various Sampling distributions, Estimating Sampling Error, Estimation of Parameters, Likelihood Estimation, MLE of a generic probability model, Properties of Estimators: Unbiasedness, Consistency, Efficiency, Sufficiency. Point and Interval Estimates and Their Reliability, Confidence Interval Estimates of Population Parameters Based on Normal, t and Chi-square Distributions.

Unit – 5: Statistical Decision Theory
Statistical Decisions, Statistical Hypothesis, Tests of Hypothesis and Significance, One-tail and Two-tail Tests. Parametric Tests: Tests Involving Normal, t, Chi-square and F Distributions - Test for Goodness of Fit, Contingency Tables, Tests for Independence of Attributes, One-way and Two-way Analysis of Variance. Non-parametric Tests: Sign Test, Run Test, Wilcoxon Signed Rank Test, Mann-Whitney U test, Kruskal-Wallis Test.

Unit – 6: Data Visualization to R
Basics of R – Vectors – Operations – Filtering - Matrices and Arrays – Matrix Operations - Lists – List Operations – List Components and values - Data Frames – Creation and Merging - Tables – Structures – Control Structures – Functions – Recursions; Data Visualization with ggplot2 – aesthetic mappings - geometric objects – statistical transformations – coordinate systems - Data transformation with dplyr – Exploratory data analysis– missing values – co variation – patterns and models – ggplot2 calls

Course Outcomes

After completing this course, the students will:

CO1: be able to visualize and summarize the data.
CO2: know the usage of probability concepts in a given situation.
CO3: be able to select a suitable distribution and also generate random samples.
CO4: be skillful in drawing samples by choosing suitable sampling techniques and estimating the parameters.
CO5: be able to formulate hypothesis and perform suitable statistical tests.

Text Books

1. Applied Statistics and Probability - by Montgomery, D. C., and Runger, G. C., For Engineers, Seventh Edition, John Wiley & Sons, Inc., 2018.
2. Fundamentals of Mathematical statistics - by S.C. Gupta and V.K. Kapoor, Sultan Chand and Sons, New Delhi.
3. Practical Statistics for Data Scientists - Bruce, P., Bruce, A., and Gedeck, P., Second Edition, O'Reilly Media, Inc., 2020.

4. The Art of R Programming: A Tour of Statistical Software Design - by Norman Matloff, NoStarch Press, First Edition, 2011.
16. R for Data Science: Import, Tidy, Transform,Visualize, and Model Data - by Hadley Wickham, Garett Grolemund, O'Reily Publications, First Edition, Feb 2017.

Reference Books

1. Statistical Methods - by N. G. Das, 1st Edition, McGraw Hill, 2008.
2. Statistical Methods Concept, Application and Computation - by Y. P. Aggarwal, Sterling Publishers, 1998.
3. Hands-on Programming with R: Write your own functions andsimulations - by Garrett Grolemund, O'Reilly Publisher, 2014.

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
2. R Programming for Data Science by Roger D. Peng

Course Code	Course Name	L – T – P	**Credits**
AMMSCD503	**Data Science with Python**	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, Hierarchal Indexing, Combing 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: Fundamental Learning Algorithms
Regression and Classification Methods, K-Nearest Neighbors (K-NN), Naïve Bayes Classifier, Support Vector Machines (SVMs), Linear Regression, Logistic Regression, Decision Trees, Random Forests, k-NN clustering, Hierarchical Clustering, Dimension Reduction, Model Evaluation and Validation Techniques.

Unit – 5: 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 – 6: 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.
CO3b 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**
AMMSCD504	**Data Science with Python Lab**	0-0-4	**2**

Course Objectives:

The course aims to introduce the basic concepts and usage of variables, expressions and practice the use offunctions 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.

Course Contents

1. Find all numbers which are multiples of 17, but not the multiples of 5, between 2000 and 2500?
2. Swap two integer numbers using a temporary variable. Repeat the exercise using the code format: a, b = b, a. Verify your results in both the cases.
3. Given two pairs of Cartesian points such as (x1, y1) and (x2, y2). Find the Euclidean distance between them. Hint: Use math module to find the square root.
4. Print the first 2 and last 3 characters in a given string. Use the string slicing concept. Do not use loops. If the length of the string is less than 5, print a suitable message.
5. Implement bubble sort. Do not use the default sort() method. Hint: So as to familiarize with the concept of sorting, and nested looping structures.
6. Implement shallow copy and deep copy of a list. You may use the copy module. Hint: While we copy a list, just a reference is copied. Hence if we make any changes to one of the lists, the same will reflect in the other as well. This is called shallow copying. Hence, in some cases we might need to deep copy, where a completely independent copy is created. This can be achieved through the deepcopy() method of the copy module.
7. Write a temperature converter program, which is menu driven. Each such conversion logic should be defined in separate functions. The program should call the respective function based on the user's requirement. The program should run as long as the user wishes so.
8. Find the largest of n numbers, using a user defined function largest().

9. Write a function that capitalizes all vowels in a string. Hint: Do not use the ASCII concept. Use the upper() method.
10. Write a function leapYear() which receives a four digit year and returns a Boolean value: True if the year is leap, False if the year is not leap.
11. Read a line containing digits and letters. Write a program to give the count of digits and letters. Hint: Instead of checking ASCII, use the in-built methods like isdigit(), isalpha()etc.
12. Write a function myReverse() which receives a string as an input and returns the reverse of the string.
13. Use the list comprehension methodology in python, to generate the squares of all odd numbers in a given list. Hint: List comprehension is one of the powerful techniques in python;
14. 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.
15. 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.
16. Write a function to find the factorial of a number using recursion.
17. Extend the above problem to find the nCr of given values of n and r. Verify the result with the help of the filter tools module, which helps to find the combinations.
18. Write a program that eliminates duplicates in a list. Do not use the concept of sets. Now, convert the original list into a set. Verify the result in both cases.
19. The user will enter five integers separated by commas. Write a program to read these values, and make a list. Print the list.Hint: They will need to read the input using raw_input(), and then split the one and only line of input using split(). Then each of the values will need to be appended to a list, which will be empty at first.
20. Generate a dictionary and print the same. The keys of the dictionary should be integers between 1 and 10 (both inclusive). The values should be the cubes of the corresponding keys.
21. 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’}}
22. 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.
23. Write a python program to find the tuples which all the elements are divided by a ‘k’ element from a list of tuples
24. Write a Python program to print all pair combinations of elements from 2 tuples. Hint: Students may use list comprehension.
25. Write a Python program to concatenate consecutive elements in tuple. Hint: use map() and tuple methods for concatenation .
26. 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
27. 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.
28. Implement Multiple plots.
29. Implement Scatter plots with histogram.
30. Implement Bubble charts.

Course Outcomes

After completing this course, the students develop the skill set to:
CO1: have knowledge of how data science is implemented in various industries.
CO2: work on hands-on exercises and projects that involve solving data-related problems using Python and Data Science techniques.
CO3: 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.
CO4: be able to analyze raw data and use different statistical methods on the data.
CO5: be able to develop programs in Python and implement functions using parameters.

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. 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.

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 Data Science Handbook Essential Tools for Working with Data – by Jake Vander Plas, O'Reilly Media, 1st edition, 2016.

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**
AMMSCD505	**Probability & Statistical Methods with R Lab**	0-0-4	**2**

Course Objectives:
This course aims to build the fundamentals of probability and statistics, make students understand the importance of probability distributions and set the mathematical foundations for data science learning. The course also introduces principles of computer organization and the basic architectural concepts.

Course Contents
Unit -1: Introduction to R and Computer Technical Specifications: Introduction to Digital Computer and Block diagram, Definition of Computer Organization, Computer Design and Computer Architecture; History and Overview of R, Basic Features of R, Installation of R, Console and Editor, Comments, Basic Arithmetic- Logarithms and Exponentials Vectors- Creating a Vector- Sequences, Repetition, Sorting, and Lengths- Subsetting and Element Extraction- Vector-Oriented Behaviour Defining a Matrix – Defining a Matrix- Filling Direction- Row and Column Bindings- Matrix Dimensions- Subsetting- Row, Column, and Diagonal Extractions- Omitting and Overwriting- Matrix Operations and Algebra- Matrix Transpose- Identity Matrix- Matrix Addition and Subtraction- Matrix Multiplication- Matrix Inversion-Multidimensional Arrays- Subsets, Extractions, and Replacements Logical Values- Relational Operators- Characters- Creating a String- Concatenation- Escape Sequences- Substrings and Matching- Factors- Identifying Categories- Defining and Ordering Levels- Combining and Cutting **Practical Component**: 1. Develop the R program for Basic Mathematical computation –Square, Square root, exponential etc. 2. Create an object X that stores the value then overwrite the object in by itself divided by Y. Print the result to the console. 3. Create and store a sequence of values from x to y that progresses in steps of 0.3 4. Confirm that the length of the vector created is 20. 5. Extract the first and last elements of already created vector from, storing them as a new object **Unit-2: Getting Used to R and Data Visualization** Describing and Visualizing Data, Using plot with Coordinate Vectors-Graphical Parameters- Automatic Plot Types-Title and Axis Labels- Color-Line and Point Appearances-Plotting Region Limits-Adding Points, Lines, and Text to an Existing Plot-ggplot2 Package-Quick Plot with qplot-Setting Appearance Constants with Geoms-- Reading And Writing Files- R-Ready Data Sets- Contributed Data Sets- Reading in External Data Files- Writing Out Data Files and Plots- Ad Hoc Object Read/Write Operations, **Practical Component:** 1. Create a database with the fields of weight, height and sex then create a plot of weight on the x-axis and height on the y-axis. Use different point characters or colors to distinguish between males and females and provide a matching legend. Label the axes and give the plot a title. 2. Create a plot using ggplot2 for the same database consists of weight on the x-axis and height on the y-axis. Use different point characters or colors to distinguish between males and females and provide a matching legend. Label the axes and give the plot a title. 3. Write R code that will plot education on the x-axis and income on the y-axis, with both x- and y-axis limits fixed to be [0;100]. Provide appropriate axis labels. For jobs with a prestige value of less than or equal to 80, use a black * as the point character. For jobs with prestige greater than 80, use a blue @. 4. 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. 5. 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. 6. Using the iris dataset, create a Pareto diagram showing the frequency of different species in the dataset.

Unit -3: Lists and Data Frames
Lists of Objects-Component Access-Naming-Nesting-Data Frames-Adding Data Columns and Combining Data Frames-Logical Record Subsets-Some Special Values-Infinity-NaN-NA-NULL- Attributes-Object-Class-Is-Dot Object-Checking Functions-As-Dot Coercion Functions

Practical Component:

1. Create a list that contains, in this order, a sequence of 20 evenly spaced numbers between -4 and 4; a 3 X 3 matrix of the logical vector c(F, T,T,T,F,T,T,F,F) filled column-wise; a character vector with the two strings "don" and "quixote"; and a factor vector containing the observations c("LOW","MED","LOW","MED","MED","HIGH"). Then, Extract row elements 2 and 1 of columns 2 and 3, in that order, of the logical matrix.
2. Create and store this data frame as dframe with the fiiels of person, sex, funny in your R workspace. Append the two new records.
3. Write a single line of code that will extract from mydataframe just the names and ages of any records where the individual is female and has a level of funniness equal to Med OR High.
4. Use your knowledge of handling character strings in R to extract all records from mydataframe that correspond to people whose names start with S.
5. Create and store a three-dimensional array with six layers of a 4 X 2 matrix, filled with a decreasing sequence of values between 4.8 and 0.1 of the appropriate length
6. Extract and store as a new object the fourth- and first-row elements, in that order, of the second column only of all layers of (5).
7. Use a fourfold repetition of the second row of the matrix formed in (5) to fill a new array of dimensions 2 X 2 X 2 X 3.
8. Overwrite the second and fourth row elements of the second column of layers 1, 3, and 5 of (5) with-99.

Unit -4 : Probability Distributions: Generate and Visualize Discrete and continuous distributions using the statistical environment, Demonstration of CDF and PDF uniform and normal, binomial Poisson distributions, generate artificial data using and explore various distribution and its properties. Densities of Random Variables, Binomial Distribution, density plots and distribution functions, Normal approximation to the Binomial distribution.

Practical Component:

1. Write an R script to generate and visualize distributions: Binomial (n=10, p=0.5), Poisson (λ=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.
2. 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.
3. Write an R script to simulate 1000 data points each from a binomial distribution with n=20 and p=0.4, and a Poisson distribution with λ=8. Calculate and plot the mean and variance for both distributions. Discuss the properties of these distributions based on your plots.
4. 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).
5. Using R, simulate a binomial distribution with n=50 and p=0.5. Approximate this distribution using a normal distribution with the same mean and standard deviation. Plot both the binomial distribution and its normal approximation on the same graph. Discuss the accuracy of the normal approximation.

Unit – 5: Statistical Analysis

Building Confidence in Confidence Intervals: Populations Versus Samples, Large Sample Confidence Intervals, Simulating Data Sets, Evaluating the Coverage of Confidence Intervals; Perform Tests of Hypotheses : Compute p-value, Relation between the critical region, the test statistic, and the p-value; Correlation: find correlation, make scatter plots, investigate relationship between two variables; Estimating a Linear Relationship: Statistical Model for a Linear Relationship, Least Squares Estimates, The R Function lm, Understanding the Residuals

Practical Component:

1. 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.
2. 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.
3. 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.
4. 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.
5. 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: Identify and execute basic syntax and programs in R.
CO2: Perform the Matrix operations using R built in functions
CO3: Carry out hypothesis testing and calculate confidence intervals; Perform linear regression models for data analysis
CO4: Perform and interpret different distribution using R
CO5: Exploit the graph using ggplot2 and other functions.

Text Books

1. The Book of R - A First Programming and Statistics - by Tilman M.Davies, Thomson Brooks/Cole. Library of Congress Cataloging-in-Publication Data, 4th Ed., 2016.
2. R for Data Science by Hadley Wickham, Garrett Grolemund, O'Reilly Publication, 2017.
3. An Introduction to Statistical Learning: with Applications in R by Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, Springer, 1st Ed., 2017.
4. Introductory Statistics with R by Peter Dalgaard, Springer, 2nd Ed., 2008.
5. Computer System Architecture by M. Moris Mano, Pearson Education/ Prentice Hall of India, 3rd Ed., 2010.

Reference Books

1. R Programming for Beginners by Steven Keller, CreateSpace Independent Publishing Platform 2016.
2. Learning R Programming by Kun Ren, Packt Publishing, 2016.
3. R Programming for Data Science by Roger D. Peng, Lulu.com, 2012.

4. Probability and Statistics with R by Maria Dolores Ugarte, Ana F. Militino, Alan T. Arnholt, Chapman and Hall, 1st Ed., 2008.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. https://web.itu.edu.tr/~tokerem/The_Book_of_R.pdf
2. https://online-learning.harvard.edu/subject/r

Course Code	Course Name	L – T – P	**Credits**
AMMSCD506	**Data Structures and Algorithms**	3-1-0	**4**

Course Objectives:

The course aims to explore basic data structures such as stacks and queues and introduce a variety of data structures such as hash tables, search trees, tries, heaps, graphs and powerful algorithms such as sorting and pattern matching.

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: compute and analyze the algorithms for efficiency using Asymptotic Notations. **CO2:** develop knowledge of basic data structures such as arrays, linked lists, binary trees, heaps, and hash tables for storage and retrieval of ordered orunordered data. **CO3:** solve problems by applying suitable data structures with the algorithms for the creation, insertion, deletion, searching, and sorting of each data structure. **CO4:** define graphs and illustrate graph traversals **CO5:** design and develop projects requiring the implementation of the data structures.
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/

SECOND SEMESTER

Course Code	Course Name	L – T – P	**Credits**
AMMSCD521	**Optimization Techniques**	3-1-0	**4**

Course Objectives:
To study the model formulation and discussion of documented real-worldapplications. Study of mathematical programming algorithms. Apply the mathematical results and numerical techniques of optimization theory toconcrete Engineering problems.

Course Contents

Unit – 1: Constrained and Unconstrained Optimization
Constrained optimization (Penalty methods, Lagrange multipliers, Karush-Kuhn-Tucker conditions). Unconstrained optimization using calculus (Taylors'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 solutionsfor 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, 10^{th} Ed., 2019. 2. Numerical Optimization by J. Nocedal, S. Wright, Springer, 2^{nd} 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, 3^{rd} Ed., 2016. 7. An Introduction to Optimization by Edwin K. P. Chong, Stanislaw H. Zak, Wiley, 4^{th} 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**
AMMSCD522	**Time Series Analysis & Forecasting Methods**	3-1-0	**4**

Course Objectives:

This course focuses on Time series analysis and growth models, to understand exponential smoothing methods, study forecasting with ARIMA models and estimate ARIMA model parameters. It also centers on the spectral analysis of weakly stationary process.

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 completing this course, the students develop the skill set to:
CO1: To learn about Exponential, Gompertz and Logistic curves and their fitting.
CO2: To understand trend adjusted exponential smoothing methods
CO3: To study MA, AR, ARMA and ARIMA models.
CO4: To understand Box-Jenkins models and estimate auto covariance and auto correlation functions.
CO5: To study Periodogram and Correlogram analyses

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**
AMMSCD523	**Machine Learning and Deep Learning**	3-0-0	**3**

Course Objectives:

This course explains machine learning techniques such as decision tree learning, Bayesian learning. It also aims to understand computational learning theory and study the pattern comparison techniques.

Course Contents

Unit – 1: Introduction

Well-posed learning problems, designing a learning system, Perspectives and issues in machine learning Concept learning and the general to specific ordering – introduction, a concept learning task, concept learning as search, find-S: finding a maximally specific hypothesis, version spaces and the candidate elimination algorithm, remarks on version spaces and candidate elimination, inductive bias; Regression: Linear, Non-linear Regression, PCA, SVMs; Decision Tree Learning – Introduction, decision tree representation, appropriate problems for decision tree learning, the basic decision tree learning algorithm, hypothesis space search in decision tree learning, inductive bias in decision tree learning, issues in decision tree learning.

Unit – 2: Deep Learning

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. 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: Bayesian learning

Introduction, Bayes theorem, Bayes theorem and concept learning, Maximum Likelihood and least squared error hypotheses, maximum likelihood hypotheses for predicting probabilities, minimum description length principle, Bayes optimal classifier, Gibs algorithm, Naïve Bayes classifier, an example: learning to classify text, Bayesian belief networks, the EM algorithm. Computational learning theory – Introduction, probably learning an approximately correct hypothesis, sample complexity for finite hypothesis space, sample complexity for infinite hypothesis spaces, the mistake bound model of learning. Instance-Based Learning- Introduction, k-nearest neighbour algorithm, locally weighted regression, radial basis functions, case-based reasoning, remarks on lazy and eager learning.

Unit – 4: Genetic Algorithms and Reinforcement Learning

Genetic Algorithms – Motivation, Genetic algorithms, an illustrative example, hypothesis space search, genetic programming, models of evolution and learning, parallelizing genetic algorithms.

Learning Sets of Rules – Introduction, sequential covering algorithms, learning rule sets: summary,

learning First-Order rules, learning sets of First-Order rules: FOIL, Induction as inverted deduction, inverting resolution.

Reinforcement Learning – Introduction, the learning task, Q–learning, non-deterministic, rewards and actions, temporal difference learning, generalizing from examples, relationship to dynamic programming.

Unit – 5: Analytical Learning

Analytical Learning-1- Introduction, learning with perfect domain theories: PROLOG-EBG, remarks on explanation-based learning, explanation-based learning of search control knowledge. Analytical Learning-2-Using prior knowledge to alter the search objective, using prior knowledge to augment search operators. Combining Inductive and Analytical Learning-Motivation, inductive-analytical approaches to learning, using prior knowledge to initialize the hypothesis

Course Outcomes

After completing this course, the students develop the skill set to:

CO1: understand the concepts of computational intelligence and various machine learning algorithms.

CO2: apply machine learning techniques to address the real time problems in different areas of science.

CO3: proficiently perform exploratory data analysis, data visualization, machine learning and big data solutions to a practical problem.

CO4: understand the broad view of machine learning and deep learning implementations in academics as well as various industries.

CO5: understand the Neural Networks and its usage in machine learning applications.

Text Books

1. Machine Learning by Tom M. Mitchell, McGraw Hill Education, 1st Ed., 2017.
2. Machine Learning: A Probabilistic Perspective by Kevin P. Murphy, MIT Press, 2012.
3. Machine Learning: An Algorithmic Perspective by Stephen Marsland, CRC Press, 2009.
4. Deep Learning by Aaron Courville, Ian Goodfellow, Yoshua Bengio, MIT Press, 2016.

Reference Books

1. Introduction to Machine Learning with Python: A Guide for Data Scientists by Andreas C. Muller, O'Reilly, 2016.
2. Python Machine Learning by Sebastian Raschka, Packt Publishing, 2015.
3. The Elements of Statistical Learning: Data Mining, Inference, and Prediction by Hastie, Tibshirani, Friedman, 2nd Ed., Springer, 2017.
4. Introduction to Machine Learning by Ethem Alpaydin, 2nd Revised edition, MIT Press, 2010.

   Python Machine Learning Case Studies by Danish Haroon, Apress, 2017.

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**
CSMSCD530	**Big Data Analysis and Algorithms**	3-1-0	**4**

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

Course Code	Course Name	L – T – P	**Credits**
AMMSCD524	**Machine Learning and Deep Learning Lab**	0-0-4	**2**

Course Objectives:

To understand the concept of Sequential Deep Neural Network and its learning process, how to improve Deep Neural Networks: Hyperparameter Tuning,Regularization and Optimization, and to build and train neural network architectures such as Convolutional Neural Networks. It also focuses on implementation of Recurrent Neural Networks, LSTMs, Transformers and other machine learning algorithms.

Course Contents

1. Creating a Data Frame in Pandas from csv files.
2. Importing Data with Pandas – adding columns to the data frame.
3. Handling Missing Data- drop, fill, aggregate functions.
4. Indexing Data Frames with Pandas, Indexing Using Labels in Pandas.
5. Exploratory Data Analysis with Pandas- for both one dimensional and two-dimensional data (series or data frames) - describe, group data, ANOVA, correlation and correlation methods, rank.
6. Calculating Mean, Trimmed Mean, Weighted Mean, Median,
7. Plotting using pandas- Exploratory analysis based on the plots.
8. Data Visualization with different charts in python.
9. Apply PCA function. Find Eigen Values and EigenVectors.
10. Working with JSON Data with python.
11. Use OpenCV to find a face in an image.
12. A weather prediction model that predicts if there'll be rain or not in a particular daywith decision tree regression concept.
13. A Python script to create a confusion matrix on a predicted model.
14. Consider a dataset where we have a value of response y for every features.
    a) Find a line which fits best and predict the response for any new featurevalues using simple linear regression.
    b) Find the errors using Least Squares technique to fine tune the model.

X	1	4	3	6	8	9	2	2
Y	2	4	3	1	3	6	5	0

15. Consider a dataset with p features (or independent variables) and one response (ordependent variable). Also the dataset contains n rows/observations.
    a. Find the regression line using multiple linear regression.
    b. Find the residual error of i^{th} observation.
16. A researcher has collected data on three psychological variables, four academic variables(standardized test scores), and the type of educational program the student is in for 600 high school students. She is interested in how the set of psychological variables is relatedto the academic variables and the type of program the student is in using Multivariate Regression.
17. Demonstrate to find the values of the parameters of a function that minimizes thecost function using Stochastic Gradient Descent.
18. A python program to explore your data with matplotlib and PCA, preprocess your data with normalization. Split the data into training and test sets. construct an unsupervised model (K-means algorithm) to fit the model to the data, predict values, and validate the model that is built.
19. Multidimensional data analysis in Python- import, Clustering, Exploratory DataAnalysis.
20. Demonstrate to perform support vector classifier on a non linear dataset using alinear kernel.
21. Introduction to Tensorflow
    a) install Tensorflow
    b) understand Tensorflow library.

    Check if the following libraries are installed
    - scipy • numpy • matplotlib • pandas • statsmodels • scikit-learn
22. Compute the function using Tensorflow library. $f(x,y) = x^2 + y^2 + 2x + y$. Find Expected Results, Check Tensorflow was installed correctly, Evaluate a functionusing Tensorflow, View the Tensor graph.
23. Implementation of AND gate using Tensorflow

24. Deep Neural Network: implement a deep neural network using Tensorflow and Keras. • train the DNN with image 2D or 3D dataset.Deep Neural Network with Regularization. Implement a deep neural network using Tensorflow and Keras.
25. train the DNN with image 2D or 3D dataset.• add regularization
26. Deep Neural Network with Dropout
    implement a deep neural network using Tensorflow and Keras.

    • train the DNN with different dataset • add dropout neurons.
27. Deep Neural Network with Early stopping
    implement a deep neural network using TensorFlow and Keras.

    • train the DNN with image 2D or 3D dataset.
    • implement early stopping
28. Build convolutional neural network model (CNN) (Basic model) forimage and other 2Dor 3D data
29. Evaluate the model using five-fold cross-validation and Develop an Improved Model
30. Develop a model for Text classification with an RNN

Course Outcomes

After completing this course, the students develop the skill set to:
CO1: understand the fundamental concepts of machine learning and deep learning, including supervised learning, unsupervised learning, neural networks, and deep neural networks.
CO2: develop a strong foundation in mathematical concepts and statistical methods that underpin machine learning and deep learning algorithms.
CO3: evaluate and compare the performance of different machine learning models using appropriate evaluation metrics and validation techniques.
CO4: explore advanced topics in machine learning and deep learning, such as convolutional neural networks (CNNs), recurrent neural networks (RNNs), and generative models.
CO5: gain practical experience in implementing machine learning and deep learning algorithms through programming assignments and projects.

Text Books

1. Python Machine Learning by Sebastian Raschka and Vahid Mirialili, Packt publishing, 2^{nd} Edition, 2017.
2. Introduction to Machine Learning with Python by Andreas C. Müller and Sarah Guido, ORielly,1^{st} Edition, 2016.
3. Machine Learning in Python by Michael Bowles, Wiley Publishers, 2018.
4. Python Machine Learning Case Studies by Danish Haroon, Apress, 2017.

Reference Books

1. Introduction to Machine Learning with Python: A Guide for Data Scientists by Andreas C. Muller, O'Reilly, 2016.
2. Python Machine Learning by Sebastian Raschka, Packt Publishing, 2015.
3. The Elements of Statistical Learning: Data Mining, Inference, and Prediction by Hastie, Tibshirani, Friedman, 2^{nd} Ed., Springer, 2017.
4. Introduction to Machine Learning by Ethem Alpaydin, 2^{nd} Revised edition, MIT Press, 2010.
5. Python Machine Learning Case Studies by Danish Haroon, Apress, 2017.

Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]

1. NPTEL Lecture on Deep Learning by Prof. P.K. Biswas, IIT Kharagpur

THIRD SEMESTER

Course Code	Course Name		L – T – P	**Credits**
AMMSCD531	**Regression Analysis and Predictive Modelling**		3-1-0	**4**

	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 Repressor's Variables, Generalized and Weighted Least Squares, Some Practical Applications; Multicollinerity: Sources of Multicollinearity, Effects of Multicollinearity. Multicollinearity Diagnostics: Examination of Correlation Matrix, Variance Inflation Factors (VIF), Eigen System Analysis of X1 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 af 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.	2. Introduction to Statistical Learning with applications in R by Gareth James, Daniela Witten , Trevor Hastie, Robert Tibshirani., Springer, 2013. 3. Regression and Other Stories by Andrew Gelman, Jennifer Hill, Aki Vehtari, Cambridge University Press, 2020. 4. Introduction to Linear Regression Analysis by Douglas C. Montgomery, Elizabeth A. Peck, G. Geoffrey Vining, Wiley India Pvt. Ltd., 3rd Ed., 2016. 5. Applied Regression Analysis by Norman R. Draper, Harry Smith, WILEY India Pvt. Ltd. New Delhi, 3rd Ed., 2015. 6. Gaussian Process for Machine Learning by Carl Edward Rasmussen, Christopher K. I. Williams, MIT Press 2005.
	Reference Books
1.	2. Applied Multivariate Statistical Analysis by Johnson, R A., Wichern, D. W., PHI learning Pvt., Ltd., 6th Ed., 2013. 3. Applied Regression Modelling by Iain Pardoe, John Wiley and Sons, Inc, 2012. 4. Applied Linear Regression Models by Michael H. Kutner, Chris Nachtsheim, John Neter, McGraw, 2004. 5. Regression Analysis by Example by Samprit Chatterjee, Ali S. Hadi, Wiley, 5th Ed., 2013. 6. The Elements of Statistical Learning: Data Mining, Inference, and Prediciton by Trevor Hastie, Robert Tibshirani, Jerome Friedman, Springer, 2nd Ed., 2009.
	Online Content [Ebooks, MOOC, SWAYAM, NPTEL, Websites etc.]
1.	2. NPTEL Lecture on Predicitve Analytics: Regression and Classification by Prof. Sourish Das, IIT Madras

Course Code	Course Name	L – T – P	**Credits**
CSMSCD540	**Artificial Intelligence**	3-1-0	**4**

Course Objectives:
The course focuses on learning the distinction between optimal reasoning Vs. human like reasoning and understand the concepts of state space representation, exhaustive search, heuristic search together with the time and space complexities. This course also aims to impart different knowledge of representation techniques and get acquainted with various applications of AI, namely game playing, theorem proving and machine learning.

Course Contents

Unit – 1: Introduction to AI
Introduction to AI - Intelligent Agents, Problem-Solving Agents, Searching for Solutions - Breadth-first search, Depth-first search, Hill-climbing search, Simulated annealing search, Local Search in Continuous Spaces.

Unit – 2: Games & Logic
Optimal Decisions in Games, Alpha–Beta Pruning, Defining Constraint Satisfaction Problems, Constraint Propagation, Backtracking Search for CSPs, Knowledge-Based Agents, Logic- Propositional Logic, Propositional Theorem Proving: Inference and proofs, Proof by resolution, Horn clauses and definite clauses.

Unit – 3: Knowledge Representation
Syntax and Semantics of First-Order Logic, Using First Order Logic, Knowledge Engineering in First-Order Logic. Inference in First-Order Logic: Propositional vs. First-Order Inference, Unification, Forward Chaining, Backward Chaining, Resolution. Knowledge Representation: Introduction to Game Playing- using First order logic-Knowledge Engineering in First Order Logic-Proportional vs First Order Logic-Resolution-Structured representation of Knowledge Using Scripts and Frames. Alpha Beta Pruning Ontological Engineering, Categories and Objects, Events.

Unit – 4: Production System & Planning
Introduction to Production system-control strategies-Rete Algorithm-Planning-STRIPS-Planning with state space search-Partial Order Planning, Definition of Classical Planning, Algorithms for Planning with State Space Search, Planning Graphs, other Classical Planning Approaches, Analysis of Planning approaches. Hierarchical Planning- Planning & acting in the real world

Unit – 5: Expert System
Expert System- Architecture and Roles of Expert System-Typical Expert System-MYCIN-XOON-DART-Case Study-Construction of simple reflex agent with sensor and actuator using Arduino

Unit – 6: Probabilistic Reasoning
Acting under Uncertainty, Basic Probability Notation Bayes' Rule and Its Use, Probabilistic Reasoning, Representing Knowledge in an Uncertain Domain, The Semantics of Bayesian Networks, Efficient Representation of Conditional Distributions, Approximate Inference in Bayesian Networks, Relational and First- Order Probability

Course Outcomes
After completing this course, the students develop the skill set to: **CO1**: formulate an efficient problem space for a problem expressed in natural language. **CO2**: select a search algorithm for a problem and estimate its time and space complexities **CO3**: apply AI techniques to solve problems of game playing, theorem proving, and machine learning. **CO4** comprehend the applications of Probabilistic Reasoning and Bayesian Networks and analyze Supervised Learning Vs. Learning Decision Trees **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. Artificial Intelligence: A Modern Approach by S. Russell and P. Norvig, Pearson India, 3rd Ed., 2015.
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 Intellience 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**
AMMSCD532	**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. Hoteling $T2$ and Mahalanobis $D2$ 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 Hardly 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**
AMMSCD533	**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**
AMMSCD534	**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**
AMMSCD535	**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 respectiveapplications 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**
AMMSCD536	**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 (lnc).
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 NLPtasks, 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 Morkov 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, Spinger 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 inan on-demand manner. It also provides an insight into what is cloud computing and the various services cloudis 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 andAndrzej 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 TimMather, Subra Kumaraswamy, Shahed Latif, O'Reilly, SPD, 2011. 4. Cloud Native Infrastructure: Patterns for Scalable Infrastructure and Applications in a Dynamic Environment by ustin 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 / Quadtrees / 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 / Hopefield 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 MethodoNS2L20logy, 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 – Ikaas 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 Minteer, 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, 2nd Edition, Chapman and Hall/CRC, 2015. 3. Hands on Artificial intelligence for IoT by Amita Kapoor, 1st 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 Intellience 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 Intellience 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 Lesser2017.
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 Defence Technology

M.Sc. In Defence Technology

SER	COURSE CODE	COURSE	L	T	P	CREDIT

SEMESTER-I

1	NA 501	Armament Technology	3	1		4
2	NA 502	Guided Missile and Radar Technology	3	1		4
3	NA 503	Information Warfare and Cyber Security	3	1		4
4	NA 504	Energetic Materials, Lasers and Fiber Optices	3	1		4
5	NA 520	Research Methodology	3	1		**4**
						20

SEMESTER-II

1	NA 505	Electronic Warfare and Sonar Technology	3		2	4
2	NA 506	Information and Communication Technology	3		2	4
3	NA 507	Statistics, Reliability and Operation Research	3	1		4
4	NA 508	Acquisition Process - Revenue and Capital	3	1		4
5	NA 552	On Job Training / Field Project (Naval Qualitative Staff Requirements)	2	2		4
						20

SEMESTER-III

1	NA 509	Artificial Intelligence and Machine Learning	3		2	4
2	NA 511	Advances in Marine Propulsion and Materials	3		2	4
3	NA 512	Infrastructure Management of Navy	2	1	2	4

4	RP 541	Minor Project - International Relations	2	2		4
5		***Elective***	-		-	4
						20

SEMESTER-IV

1	NA 513	Naval Planning Process	2	1	2	4
2	NA 518	Geopolitical Studies	2	1	2	4
3	RP 542	Dissertation	-		-	12
						20
		Total Credits				**80**

ELECTIVE

1	NA 554	Skill Development (Prezi, Power BI, Advance Excel, AI & Data Science)
2	NA 555	Open Elective from any Department

Course Code	Course Name	L-T-P	**Credits**
NA501	***Armament Technology***	3-1-0	4

Course Objectives:

- Understanding the basic principles of armament technology, including the physics & engineering behind weapon systems.
- Understanding the mechanics & dynamics involved in operation of different weapons.
- Learning about the electronic & control systems that are integral to modern armaments.

Course Contents

Unit I

Explosive Technology and Polymers: Military Explosives, Propellants, Pyrotechnics, Modern Engineering Materials, Rubbers and Elastomers, Fuels and Lubricants, Ammunition.

Unit II

CBRN (NBC): CBRN threat perceptions, radiation exposure status and op exposure Guidance, Procedure for decn drills, detection and quarantine, CBRN Organisation and training set up in all three services incl their scaling, Duties of staff offrs at various levels and action / reports required to be taken / generated post CBRN attack, CBRN warning sys and CBRN message interpretation, Future and present battle field in r/o CBRN warfare, Armed forces preparedness wrt CW & BW.

Unit III

Armament: Armament Engineering, Fire control system, Naval Armament, Guided Naval Armaments, Naval Gun Fire Support and requirement of migration to heavy calibre guns on naval ships, Electro-Magnetic Rail Guns, Advanced Hit Efficiency and Destruction (AHEAD) Ammunition, Magneto Hydrodynamic Explosive Munitions.

Unit IV

Underwater Weapons: Heavy Weight and Light Weight Torpedoes, Super Captivating Torpedoes, Processor Based Mines, Torpedo Defence Systems, Extended Range Anti-Submarine Rocket, Adaptive beam control optics and software algorithms to fine tune energy into focused beam, High Power Microbeam.

Unit V

Air Armament: Aircraft Gun ammunitions, Bombs and Fuzes, Classification and requirement of aircraft bombs, Construction, description and functioning of various bombs and fuzes& New Generation fuzes and its requirement, Principles of rocket technology, Construction features of aviation rockets, Rockets of IAF inventory and its capabilities.

Course Outcomes:

CO1: Apply armament technology knowledge in practical scenarios, such as defence, aerospace& security sectors**.**

CO2: Keep abreast of current trends, advancements and future technologies in the field of armament technology.

CO3: Work effectively in multidisciplinary teams, communicating technical information clearly & efficiently.

Text Books

1. Armament Engineering by H Peter

Reference Books

2. Introduction to aerodynamics by john D Anderson.

Course Code	Course Name	L-T-P	**Credits**
NA502	***Guided Missile and Radar Technology***	3-1-0	4

Course Objectives:

- Identify & describe the major components & sub systems of guided missiles & radar systems, such as propulsion, guidance, control, targeting &tracking.
- Learn methods for target detection, identification, & tracking using radar systems.
- Explain the basic principles of radar operation.

Course Contents

Unit I

Introduction to guided missiles: Missile System, Missile Propulsion Missile Aerodynamics Missile Guidance Missile Control, Smart Munitions with flight path control for loitering capability, Scramjet technology in missile propulsion, Hypersonic Missiles, Multi-Spectral and Multi Lens Missiles Seekers, Size, weight and power (SWaP) – Constrained enhanced electronics for sensors, Guidance and Communications.

Unit II

Radar Technology: Basic Principle and Properties of Electro Magnetic Waves, Basic terminology of Radar, Principle of Radar, Radar Range Equation, Operating Principle of Radar Transmitter, Operating Principle of Radar Receiver.

Unit III: Types of Radar Antennas and their characteristics, Types of Displays and applications, Operating Principle of Pulsed Radar, Operating Principle of CW Radar, velocity measurement of Target, Operating Principle of FMCW Radar, Range measurement using FMCW radar, Operating Principle of MTI Radar, explanation of Blind speeds and Delay Line Canceler.

Unit IV: Operating Principle of Tracking Radar, Types of tracking, Range Gate Tracking, Operating Principle of Phased Array Radar, Types of arrays, Principles of Beam Forming and Beam Steering, Introduction to Link II System. Configuration of Link-II Mod-III**.**

Course Outcomes:

CO1: Gain a thorough understanding of the principles & theories underlying guided missile & radar systems.

CO2: Learn the operational aspects of missile guidance systems, radar systems & their components.

Text Books:

1. Principle of Modern Radar and Missile Seaker by Evgeny Marhin.

Reference Books:

1. Introduction to naval armament by Radm OPS Rana**.**

2**.** Missile guidance & control systems by George M Siouris.

Course Code	Course Name	L-T-P	**Credits**
NA503	***Information Warfare and Cyber Security***	3-1-0	4

Course Objectives:--

- Recognize various types of cyber threats & attacks.
- Learn about cyber defence mechanisms & strategies.
- Explore emerging technologies in cyber security.

Course Contents

Unit I

Introduction of Information Warfare-Role of Information in Warfare, EW vs IW, Information Environment, Evolution of IW, Enabling Technologies, OODA Loop (Decision Cycle).

Unit II: Basic Engagement Model (Edward Waltz), Spectrum of IW, Relevance of IW, Objectives of IW, Defining features of IW, Principles of IW, Components of IW, Application of IW, IW Vision, Effects of offn IW, Objectives of offn IW, Effects of Def IW, Objectives of Def IW, IW Planning Process & Key

Unit III: Issues, Definition, Aim, Principles of Psychology Warfare,Objectives of Psychology Warfare, Psychology Operations Roles, Category of Psychology Operations, Types of Psychology Operations, Benefits, Planning Considerations, Agencies & their Responsibilities, Audiences, Key Communicators, Classification of Audiences, Types of Audiences, Theme types, Theme Selection, Symbol, Symbol Selection. Analysis & Techniques of Counter Psychology Operations.

Unit IV

Introduction of Cyber Security - Cyber Security Vulnerabilities and Cyber Security Safeguards, Securing Web Application, Services and Servers, Intrusion Detection and Prevention, Cryptography and Network Security, Cyberspace and the Law, Cyber Forensics, Cyber Security for Naval Officer,

Unit V

Organisation of IHQ-DIW/NCG and Commands CCOSW, Cyber Security Governance, Vulnerability Assessment Methodology, Risk Management Framework, Disaster Recovery, Business Continuity and Crisis Management Plans, Emerging Threats and Defences.

Course Outcomes:

CO1: Recognize & articulate various types of cyber threats, vulnerabilities & attack methods.
CO2: Understand the various facets of info environment.

Text Books:

1. Introduction to Communication Electronic Warfare Systems by Richard Poisel.

Reference Books:

1. Information Warfare and Cyber Security by Dr. P. K. Sharma
2. Cyber Warfare by Paul J. Springer

Course Code	Course Name	L-T-P	**Credits**

NA504	***Energetic Materials, Lasers and Fiber Optices***	3-1-0	4

Course Objectives:-

- Understand the fundamental principles of laser operation including stimulated emission, population inversion optical cavities.
- Study the diverse applications of lasers in fields like medicine, communication.
- Understand the basic principles of light propagation in optical fibers.
- Learn about different types of optical fibers.

Course Contents

Unit I

Introduction of Energetic Materials, LASERS - Concept of Coherence, Absorption, Spontaneous Emission and Stimulated Emission Processes, Population Inversion, Pumping, Gain, Optical Cavities, Main Components of Laser, Principle of LASER Action.

Unit II: Introduction to General LASERS and their types. Three &Four level LASERS, CW & Pulsed LASERS, Atomic, Ionic, Molecular, Excimer,Liquid and Solid-State LASERS and Systems, Short Pulse Generation and Measurement,

Unit III

Laser: Laser Applications in Medicine and Surgery, Materials Processing, Optical Communication, Metrology and LIDAR and Holography, LASER weapons.

Unit IV

Introduction of Fiber Optices : Geometrical Optics Description of Step and Graded-Index Fibers, Wave Optics Description, Modes in Step-Index Fibers, Dispersion in Single-Mode Fibers: (Group-Velocity and Polarization-Mode, Dispersion-Induced Limitations, Losses, Nonlinear effect), Applications of Fiber Optics.

Course Outcomes:

CO1: Understand the basic principles of light propagation in optical fibers.

CO2: Learn about different types of optical fibers.

Text Books:

1. Optronics, Fiber Optics and Laser Coursebook by Thomas Petruzzellis

Reference Books:

1. Shantanu Bhattacharya, Avinash Kumar Agarwal, T. Rajagopalan, Nano-Energetic Materials, Springer Nature Singapore Pte Ltd. 2019.
2. A. K. Ghatak & K. Thyagarajan, Optical Electronics, Cambridge University Press,1989. References
3. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)

Course Code	Course Name	L-T-P	**Credits**
NA520	***Research Methodology***	3-1-0	4

Course Objectives:

- Understanding the fundamentals of research & its methodology.
- Knowledge of manuscript preparation, patents and intellectual property.
- Technology transfer & 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, 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 database, Geographical Indicators.

Unit VI: New Development 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:
CO1: Understanding the fundamentals of research & its methodology.
CO2: Knowledge of manuscript preparation, patents and intellectual property.
CO3: Technology transfer & application of IPR in various domains.
CO4: Choose the appropriate research design and develop appropriate research hypothesis for research project.

Text Books:
1. Research Methodology by Kothari C R

Reference Books:
1. Mayall, **“**Industrial Design’’, Mc Graw Hill, 1992.
2. **Niebel, “Product Design’’,** Mc Graw Hill, 1974.
3. Asimov, **“**Introduction to Design**’’**, Prentice Hall, 1962.

Course Code	Course Name	L-T-P	**Credits**
NA505	***Electronic Warfare and Sonar Technology***	3-0-2	4

Course Objectives:
- Understand the basic principles & importance of EW in modern military operations.
- Study various types of EW systems, including radar, communications.
- 3. Understand methods of electronic jamming & deception.

Course Contents

Unit I
Introduction of Electronic Warfare : Electromagnetic Environmental Effects (E3), Electromagnetic Noise, EMI Triangle, Emissions, Susceptibility, Coupling Paths, Historical Examples / Incidents related to EMI/EMC, Decibel (dB), dBm, dBi, dBc, Conducted Voltage (dBμV), Conducted Current (dBμA), Radiated Electric Field (dBμV/m), Radiated Magnetic

Field (dBpT), Near & Far Fields, Power Density, Standards Bodies in the World (ITU, IEC, CISPR, CENELEC, FCC, IEEE, SAE, GOST, VCCI etc).

Unit II: Difference between Commercial & Military EMI/EMC Test Standards, Examples of Commercial Test Standards & Military Test Standards, MIL-STD-461, Applicability of MILI-STD-461 Tests, Typical CE, CS, RE & RS tests (test setup and method) Grounding, Bonding, Shielding, Filtering.

Unit III: Operational methods to contain EMI; EMC in design (of equipment and platforms); Operational Problem Analysis & Solution, HERF, HERP, HERO, Limits of safety in standards, Test Methods, Precautions to be taken.

Unit IV

Sonar Technology: Oceanography and Underwater Acoustics, Sound Transmission in the Ocean, Propagation Characteristics, Ray, Acoustics & Shadow Zones.

Course Outcomes:

CO1: Demonstrate a thorough understanding of electronic warfare principles & their importance in military operations.

CO2: Identify & describe various types of EW systems, including radar, communications.

Text Books

1. Electronic Warfare by Dave Adany.

Reference Books:

1. Richard Poisel, Search Results Antenna Systems and Electronic Warfare Applications, Artech House.
2. Underwater Acoustic System Analysis by W S Burdic

Course Code	Course Name	L-T-P	**Credits**
NA506	***Information and Communication Technology***	3-0-2	4

Course Objectives:

- Understanding basic concepts of networking.
- Learning on network models.
- Understanding protocol & standards.
- Basics of IP addressing.
- Learning on Networking Hardware.
- 6. Foundation on basic computer architecture.

Course Contents

Unit I

Introduction of Computer Networking - Data communication & Computer Networks – Transmission Media, Digital &Analog Transmission, Routing, Network Topologies, Various Network types like LAN, WAN, MAN, Introduction to Networking Components like HUB, Router, Switches, ISO / OSI model, Introduction to Wireless Networks. Internet and Applications like e-mail, FTP, Telnet, WWW etc.

UnitII

Introduction of Basic Communication - Elements and Brief Description of a Communication System, Modulation, RF frequency bands with Typical Applications. Propagation of Radio waves, Tropo-Scatter, SATCOM. Ground Waves, Sky Wave, Atmospheric Effects on Sky Wave Propagation

Unit III

Introduction of Satellite Communication-Satellite Orbits, MIMO in HF and Tropo Scatter Communications, Satellite Navigation Systems.

UnitIV

Introduction of Computer Networking- Data communication & Computer Networks – Transmission Media, Digital &Analog Transmission, Routing, Network Topologies, Various Network types like LAN, WAN, MAN, Introduction to Networking Components like HUB, Router, Switches, ISO / OSI model, Introduction to Wireless Networks. Internet and Applications like e-mail, FTP, Telnet, WWW etc

Course Outcomes:

CO1: To have comprehensive foundation for student officers to understand design, implement & manage network systems effectively.

Text Books

1. Information and Communication Technology by Javed Khan.

Reference Books:

1. TCP/IP protocol by forouzan.
2. Computer network by Tanenbaum

Course Code	Course Name	L-T-P	**Credits**
NA507	***Statistics, Reliability and Operation Research***	3-1-0	4

Course Objectives:

- Understand fundamental statistical concepts & terminology.
- Understand the basic concepts of reliability & its importance in engineering & product design.
- Understand the scope & significance of operations research in decision-making & problem-solving.

Course Contents

Unit I

Introduction of Reliability–Engineering Types of Statistics (Descriptive and Inferential Statistics), Types of Data (Primary/ Secondary, Grouped/ Ungrouped and Qualitative/ Quantitative) and Data Representation (Textual, Graphical and Tabular).

Unit II: Measures of Central Tendencies (Mean, Mode & Median) for Grouped and Ungrouped, Measures of Dispersions (Mean Deviation and Standard Deviation), Basic Axioms of Probability, Tree Types of Events: Dependent/ Independent, Mutually Exclusive/Not Mutually Exclusive Events.

UnitIII

Operation and Research - Overview of OR techniques, Linear Programming (Formulation and Finding initial basic feasible solution, Optimality check of Solutions, Simplex Method, Introduction to Duality, Sensitivity &Degeneracy) and Introduction to Goal Programming.

Unit IV: Transportation Models (LCC & VAM), Optimization of Transportation Models and Transshipment Problem, Assignment Model &Hungarian Algorithm, Network Models, Minimum Spanning Tree Problem, Prim's Algorithm, Kruskal's Algorithm. **Unit V:** Decision Theory, Forced Decision Matrix, Decision Matrix, Various Criteria for Decision Making.
Course Outcomes: **CO1:** Apply basic principles of probability to statistical problems and understand various probability distributions. **CO2:** Use various reliability metrics & models to assess & predict system reliability.
Text Books 1. Operational Research By P Rama Murthy
Reference Books: 2. Operations Research: Theory and Applications by J.K. Sharma

Course Code	Course Name	L-T-P	**Credits**
NA508	***Acquisition Process – Revenue and Capital***	3-1-0	4

Course Objectives:

- Different plans in capital acquisition.
- Organisation structure of MoD & SHQ in capital acquisition.
- Planning & approval process of different plans.

Course Contents

Unit I

Introduction of Revenue Procurement -GFR 2017 and DFPDS 2016-Organisation structure in MoD and Service HQ for Revenue Procurement, Schedules of Financial powers and Delegated Financial Powers Annual Revenue Procurement Plan (ARPP).

UnitII

Integrated Logistics -Concept of RML (Revolution in Military Logistics), Modernization of Logistics in Armed Forces, e- Logistics Initiatives in Armed Forces and its Impact, Benefits of Integrated Logistics in Armed Forces.

Unit III: Formulation of SOC, RFP, TEC, Commercial Bid, Analysis and conduct of CNC, Contract formulation as per DPM, e-Procurement through CPPP and GeM.

Unit IV

Capital Procurement & DAP - Classification/Categorization Jargon, Acquisition – Organization/Structure, Acquisition Planning Process, Initiation of project, RFI and SQRs formulation, Process flow, RFP and evaluation, OCPP, Challenges and Sum-up, Challenges in Capital Procurement along with case study.

Course Outcomes:

CO1: Different plans in capital acquisition.
CO2: Organisation structure of MoD & SHQ in capital acquisition.
CO3: Planning & approval process of different plans.

Text Books: 1. DPM & DAP by Govt of India, MoD
Reference Books: 1. DAP-2020 2. GFR-2017

Course Code	Course Name	L-T-P	**Credits**
NA509	***Artificial Intelligence and Machine Learning***	3-0-2	4

Course Objectives:

- Learn the basic concepts of AI & ML.
- Encourage critical thinking & innovation in AI & ML.
- Study various AI & ML algorithms & techniques.

Course Contents

Unit I

Introduction of Artificial Intelligence (AI)- History of AI, Researchers Computer Scientists like Alan Turing, John McCarthy, Marvin Minsky and Geoffrey Hinton, Key concepts like the Turing Test Difference between AI and ML.

Unit II: Data as lifeblood of AI, Algorithms for finding patterns to work with data in an AI project.

UnitIII

Introduction of Machine Learning -Traditional Statistical Techniques like Regressions, Algorithms, Overview of Advanced Algorithms such as k-Nearest Neighbor (k-NN) and the Naive Bayes Classifier, Putting together a Machine Learning Model.

Unit IV

Deep Learning - Neural Networks to find patterns that mimic the brain, Introduction to Algorithms like Recurrent Neural Networks (RNNs), Convolutional Neural Networks (CNNs), and Generative Adversarial Networks (GANs).

Course Outcomes:

CO1: Grasp fundamental principles & theories of AI & ML.

CO2: Understand ethical considerations & societal impacts of AI & ML.

Text Books

1. AI By David Brown

Reference Books:

2. Basics Of Artificial Intelligence & Machine Learning by Dr. Dheeraj Mehrotra

Course Code	Course Name	L-T-P	**Credits**
NA511	***Advance in Marine Propulsion and Materials***	3-0-2	4

Course Objective:

- Gain a comprehensive understanding of various marine propulsion systems, including conventional & advanced technologies.
- Study real world case studies to understand the practical challenges & solution in the implementation of advanced marine propulsion systems & materials.
- 3. Investigate the common failure modes of marine propulsion systems & materials & develop maintenance strategies to enhance reliability & longevity.

Course Contents

Unit I

Introduction Marine Propulsion - Propulsion Systems, Transmission Systems and Propellers, Service Conditions and Formulation of Staff Requirements for Propulsion Systems.

Unit II

Resistance - Hydrodynamic Resistance, Interaction of Hull and Propeller, Power Demand, Load and Drive Characteristics, Types & Configurations of Propulsion System packages feasible.

Unit III: Power Plant Concepts: Direct Drive, Geared Drive, Multiple Shaft and Combined Drives, Electrical Concepts, all Electric ship Concept and Hybrid drives. Matching criteria: Design Speed, Design and Off-Design conditions, Fuel Consumption and Emissions, Technical Evaluation of various equipment of the integrated Propulsion System, Methodology of Propulsion System Integration at Design and Implementation Stages.

UnitIV

Marine Materials - Marine Environmental Challenges Dictating Specifications of Marine Materials, Introduction to Corrosion and Corrosion Control Techniques used for Marine Platforms, Specific Marine Material selection at Design Stage for Marine Equipment, Marine Material trends in indigenised Ships/ Submarines and Technical/ Manufacturing Challenges, Future Trends in Marine Materials for the Newer Platform and the Lifecycle Effects of the same, Indigenised Capabilities of R&D and Industry Partnership.

Course Outcomes:

1. Demonstrate a thorough understanding of various advanced marine propulsion systems.
2. Identify & solve complex problems related to the performance, maintenance & reliability of marine propulsion systems.

Text Books:

1. Marine Propellers and Propulsion.

Reference Books:

1. Internal Combustion Engine Theory and Practices, 2nd Ed, Vol I & 2, Charles Fayette Taylor, MIT Press, 1999.

Course Code	Course Name	L-T-P	**Credits**
NA512	***Infrastructure Management of Navy***	2-1-2	4

Course Objective:

- Conceptualization of project catering for future developments.
- Defining the necessity of the project.
- Preparation of project requirements & justification of project.
- Tendering action & associated activities.

Course Contents

Unit I

Infrastructure Management of Navy -Conceptualization / Necessarily of project, study in detail *actions* from Approval in Principal (AIP) to Letter of Acceptance (LoA) (NIT for EoI, Short listing of Consultants, Finalization of SoW/ RFP, Pre-Bid Meeting, Opening and Evaluation of T-Bid/ Q-Bids, LoA).

Unit II: Study in detail actions from Letter of Acceptance (LoA) to Draft Project Report (DPR). Issue of WO, Contract Conclusion, Kick Off Meeting/ Site Meeting, Land Utilisation and Feasibility Report, Finalization of DPR, NOC from various agencies, Environmental Clearance.

UnitIII: Processes and formalities for Project Sanction, Execution and Completion, Life Cycle Management of Infrastructure Project.

Unit IV: Visit to DGNP (Mbi/ Vzg), Case Study of completed / ongoing / future ATWP Projects including guarantee/ payments / legal issues if any.

Course Outcomes:

1. Conceptualization of project catering for future developments.
2. Defining the necessity of the project.
3. Preparation of project requirements & justification of project.
4. Tendering action & associated activities.

Text Books:

1. SADs by GOI.

Reference Books:

2. Recapitalizing the Navy: A Strategy for Managing the Infrastructure by National Academies Press

Course Code	Course Name	L-T-P	**Credits**
NA513	***Naval Planning Process***	2-1-2	4

Course Objectives:

- Analyze the fundamental principles & methodologies of strategic naval planning.
- Develop skills to create & implement operational plans that address various scenarios, ranging from peacetime operations to wartime contingencies.
- 3. Analyze the logistical requirements & challenges of sustaining naval operations, including supply chain management, maintenance and personnel support.

Course Contents

Unit I

Basics of Planning-Why We Plan, Military Planning, Planning Principles, Military Planning Logic.

Unit II

Naval Operational Planning- The Naval Process, The Naval Component Planning, Execution Co-ordination, Planning Products, Additional Service Responsibilities.

Unit III: Joint Operation Planning- National Response, Military Action, Joint Operations Planning Processes, Campaign Planning, Ready to Fight Prepared through Planning.

Unit IV

Military and Political Planning Structure- Flexible decision making and Command, Logical Framework within Naval Staff, Evaluation of the Situation, Translation of decision into Subordinate Action.

Course Outcomes:

CO1: Demonstrate the ability to develop comprehensive strategic naval plans that address mission objectives, threat assessments & resource allocation.

CO2: Create & implement detailed operational plans for various scenarios including peacetime operations, crisis response and wartime contingencies

Text Books:

1. Indian Naval Book Reference- 08

Reference Books:

Course Code	Course Name	L-T-P	**Credits**
NA518	***Geopolitical Studies***	2-1-2	4

***Course Objectives*:**

- Develop a thorough understanding of the fundamental concepts and theories of geopolitics, including historical evolution of geopolitical thought.
- Analyze the distribution & dynamics of global power, including the roles and influence of major state & non-state actors in international relations.
- 3. Study the geopolitical characteristics and strategic importance of different regions, including the middle east, Asia-Pacific, Europe, Africa and the Americas.

Course Contents

Unit I
Physical and Economic Components of India's Geography- Physical Component, Location, The Northern Belt, The Eastern Region, The Central Plains, The Deccan Plateau, The Coastal Belt, The Western Thar Desert, The Western Plains, Island Territories, Different Economic Components.

Unit II
Human Component of India's Geography- Population – Size, Growth Rate and Distribution, Social Structure, Population and Social Characteristics, Religion, Language, Literacy, Cultural Environment.

Unit III
Geographical Imperatives for India's Security-Imperatives from Physical, Economical and Human Components of Geography.

Unit IV
India's Military Elements as it exists Today- Composition of India's Armed Forces, Organization Command And Control, Recruitment and Training, Territorial Army and Para Military Forces, Weapons And Equipment- Manufacturing and Procurement Policies, Mobilization and Deployment, Nuclear Option Factor, Missile Technology and Development, Defence Research and Development Infrastructure.

Unit V
Relationship Between India's Geographic Element and its Military Element-Force Projection, Use of Military Assets, Necessity for Sturdy Weapons and Equipment, regional Based Employment Philosophy, India's Role in Assisting Regional Stability.

Course Outcomes:
CO1: Demonstrate a deep understanding of key geopolitical concepts, theories and historical developments.
CO2: Analyze global power dynamics and the roles of state and non-state actors in international relations.

Text Books:
1. Politics and Geopolitics By Harsh V Port

Reference Books:

Course Code	Course Name	L-T-P	**Credits**
NA554	***Skill Development (Prezi, Power BI, Advance Excel, AI and Data Science)***		4

***Course Objective*:**

Course Contents

(A) Skill Enhancement - Prezi Presentation
Unit I: Introduction -Prezi versus Power Point - An Introduction to Non-Linear Presentations.
Unit II: Planning& Designing Prezi - The Importance of Planning, Useful Techniques - Mind Mapping,Brain Dump,Lists, BIG Picture, Best practice when choosing imagery.

Unit III: Working with Basic Content, Prezi Basics, Creating your Prezi, Using the Theme wizard, Frames - Inserting and grouping with Frames, Contents - Inserting Text, Images, Shapes, Diagrams, Video, Sound, Web-Link, Re-arranging content with favorites, Arranging and Zooming elements, Understanding 3D Background.

Unit IV: Preparing for a Coaching Session, Collaborating with other on Prezi, Presentation options and Considerations - Portable Prezi, Desktop App, Remote option, Sharing and Publishing your Prezi.

(B) Skill Enhancement - Power BI

Unit I: Getting Started with Power Query, Starting with 99 Functions (Text, Date, Number), Appending Clean Data in Power Query.

Unit II: Merging data in Power Query - DON'T USE VLOOKUP, Transformation of data in Power Query without coding, Conditional Columns and Flash fill, Custom Columns.

Unit III: Stop to Understand the Confusing things in Power Query, Automating your daily routine task with Power Query, Exploring other visuals.

Unit IV: Working with Interactive Slicers in Power BI, Working with Powerful Filters in Power BI, Using objects to Enhance reports in Power BI.

Unit V: Introduction to Power BI Service, Creating a Dashboard in Power BI Service, Automating Reports and Dashboards, Introduction to Power Pivot.

(C) Skill Enhancement – Advance MS Excel

Unit I- Basic of Excel Sheets, Tables and Conditional formatting

Unit II - Getting Started with Basic Excel Functions, Working with Advanced Excel Functions

Unit III- Working with Data, Lookup Functions

Unit IV- Hyperlink, Introduction to Charts, Graphs and Maps

Unit V- Introduction to World of Pivot Table and Pivot Charts, Print Settings and Security

(D) Skill Enhancement – Artificial Intelligence and Data Science

Unit I: Artificial Intelligence, Natural Language Processing, Speech Recognition, Computer Vision, Artificial Neural Networks, Automatic Programming. Planning and Decision Support/ Expert Systems.

Unit II: Linear AlgebraLinear Algebra: Scalars, Vectors, Matrices and Tensors, Matrix Multiplication, Identity and Inverse Matrices, Linear Dependence and Span, Norms, Special Kinds of Matrices and Vectors, Eigen Decomposition, Principal Component Analysis. Chain Rule, Partial Differential Equations-Applications in finding the Minima and Maxima of a function.

Unit III: Statistics for Data Science Types of Statistics, Correlation, Covariance, 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, Analysis of variance ANOVA. **Unit IV:** Bayesian and Perceptron Learning, Probability Bayesian learning, Maximum Likelihood Hypothesis, Naïve Bayes Classifier, Artificial Neural Networks- Perceptron's, Feed forward Neural Networks, Back Propagation. Fuzzy Logic **Unit V: Probability Theory-** Random variables, Probability Distributions, Marginal Probability, Conditional Probability, Chain Rule of Conditional Probabilities, Expectation, Variance and Covariance, Common Probability Distributions. **Unit VI: Image Processing-**Image Processing Fundamentals, Different Types of Images, Image Enhancement in Spatial Domain. Spatial Filtering using Convolution Filters. Histogram processing – Basics of Spatial Filtering–Smoothing and Sharpening.
Course Outcomes: Enhancement of skills in Artificial Intelligence and data science
Text Books:
Reference Books:

M.Sc. in Tank Technology

<u>M.Sc. in Tank Technology</u>

(Starting from January 2024)

SEMESTER I					
No	**Course Code**	**Course**	**L**	**T/P**	**Credit**
1	TTC 501	Orientation and Introduction to Tank	3	1	04
2	TTC 502	Orientation and Introduction to ICV/BMP.	3	1	04
3	TTC 503	Basic Science & Technology - I	3	1	04
4	TTC 504	Fundamental of Armament Technology	3	1	04
5	TTC 505	Advance Science & Technology - I	3	1	04
SEMESTER II					
1	TTC 506	Basic Science & Technology - II	3	1	04
2	TTC 507	Military Autonomous System	3	1	04
3	TTC 508	Armourd Fighting Vehicle Armament Technology	3	1	04
4	TTC 509	Armourd Fighting Vehicle Propulsion Technology	3	1	04
5	TTC 510	Advance Science & Technology - II	3	1	04
SEMESTER III					
1	TTC 511	Combat Power Application: Doctrine	-	-	4
2	TTC 512	Combat Power Application: Operations	-	-	4
3	TTC 513	Combat Power Application: SD Aspects	-	-	4
4	TTC 514	Syndicate Technical Studies	-	-	8
SEMESTER IV					
1	TTC 515	Dissertation	-	-	16
2		Elective	-	-	04
		Credits Total			**80**

(b) **<u>Open Electives.</u>**

Students may choose from following subjects as Elective courses: -

(i) Advance Presentations Skill.

(ii) Leadership and Combat Management.

(iii) Massive Open Online Course (MOOC).

DETAILED SYLLABUS OF SEMESTER -I

<table>
<tr><td>Course Code</td><td>Course Name</td><td>L – T – P</td><td>Credits</td></tr>
<tr><td><u>TTC 501</u></td><td><u>Orientation and Introduction to Tank</u></td><td>3-1-0</td><td>4</td></tr>
<tr><td colspan="4">Course Objectives: To familiarize students about the fundamentals Tanks and types of and their components</td></tr>
<tr><td colspan="4">Course Contents

1. Unit I : Eqpt Automotive Sys - Introduction Gen Hull & Turret , Power plant and pack , details of Eng Lubrication Sys , Engine Cooling Sys , Supercharger & Turbocharger, Flywheel & Torque Convertor, Ign sys, clutch Fuel Sys & FIP, Injector & Governor, Brake Sys, Steering Sys, Transmission Sys , Txn Lub Sys , PNVD, NBC Sys, IFDSS , Fording capb and APU. Critical comparison of MBT ARJUN, T-72 and T-90 including current challenges and special systems under trials
2. Unit II : Eqpt Armament Sys - Introduction to 120 mm/125mm Gun, Gun Control System, Amn, Loading and Breech Mech, Stab sys ,FCS, FCC sys , GCB Operating Proc , Gunner Main Sight & Cdr Panoramic Sight, Co axial MG and AAMG sys and missile system operation of MBT ARJUN, T-90 & T-72.
3. Unit III : Eqpt Radio Sys - Gen orientation, controls and operation, setting up, fault finding, secrecy and AJ mode, data communication , txn, operational limitation of the Radio system RS CNR 900M,RS STARS V MK-II,RS CNR AFV (I),DCH VIC:500,RS VRC 6100M and BFSR (SR). Latest trials IDex projects incl SDR sys, IFF sys and BMS under prog for tanks.</td></tr>
<tr><td colspan="4">Course Outcomes:
Knowledge and applications of major components of tanks
Comparisons of contemporary tanks and understand their features</td></tr>
<tr><td colspan="4">Text Books: Technology of Tanks, <u>Richard M. Ogorkiewicz</u>, 1991</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="4">Reference Books: Tanks and Armored vehicles, Tim Cooke, Capstone Press</td></tr>
</table>

Course Code	Course Name	L – T – P	**Credits**
TTC 502	**Orientation and Introduction to ICV/BMP**	3-1-0	**4**

Course Objectives: To familiarize students with various combat vehicles with automation and communication systems

Course Contents

1. **Unit I : Intro & Orientation to BMP/ICV -** Introduction and familiarization with BMP-II and Variants, Peculiarities of Mechanised Infantry vehicles, Amph Capb of BMP-II & BRDM, Emp of ICVs in Urban Warfare and prog of FICV, Introduction to 30 mm Cannon, Operation of Stabilisation System & Target Designation System, Elecro-Optical System , Konkurs-M Missile System, Main & co axial weapon system, introduction to NAG Msl Sys & NAMICA.
2. **Unit II : ICV Automotive Systems –** Intro and familiarisation of automotive sys to include power plant, txn system, fuel system, cooling system, lubrication system, steering sys with details of planetary steering mechanism, brake system, maint in short term and long term, challenges of terrain on operation including flotation.
3. **Unit III : ICV Armament and Communication Systems –** Intro to 30 MM Cannon to include zeroing procedure, stab system and ballistics, ammunition and restrictions, co axial weapon system and restrictions, sighting system including fault finding and diagnois, latest R&D and upcoming/undergoing trials and projects

Course Outcomes

Types of Infantry vehicles and their requirements
Integration of Automative systems, Armaments and communication systems into BMPs

Text Books: BMP Infantry Fighting Vehicle, Steven J. Zaloga · 2013

Reference Books: BMP 1, Miroslaw Skwiot · 2009

Course Code	Course Name	L – T – P	**Credits**
TTC 503	**Basic Science & Technology - I**	3-1-0	**4**

Course Objectives: To impart fundamental knowledge in the fields of electronics, applied mechanics, thermodynamics and hydraulic

Course Contents

1. **Unit I : Fundamentals Of Electronics & Communication Technology -** Principles of Elecs & Comn Sys, HF, VHF/UHF, AM, FM and Digital Modulation , Microwave Tropo scatter, Satl Comn Sys, Optical Fibre Comn Sys, GPS and Satl Positioning Sys, Principles of Info Warfare, Examples of Elecs Sys in Modern Tks, Regulate Power Supply Test Kit, BJT Amplifier And Emitter Follower Test Kit & Digital Cct Test Kitt, AM, FM and Digital Modulation, Army Communication Networks including typical equipment used in the Army,

ASCON, TCS and Tank Communication, EW, ESM, ECM, ECCM, WIMAX and CDMA/Mobile Cellular Tech.

2. **Unit II : Fundamentals of Applied Mechanics -** Moment of force, moment about axis, equivalent force Equations of equilibrium, free body diagrams, Dry Friction & sliding friction, experiment on Reactive Forces when a Simply Supported Beam is loaded with Weight, Experiment on law of Parallelogram for different Forces applied on Pulleys, Strength of Materials: Simple stresses and strains, Hooke's Law Elastic limit, yield Point, Ultimate Strength, Young's modulus, Shear forces and bending moments, Stresses and strains in torsion bars, Experiment on Mild Steel/ Deformed Bar for obtaining Stress vs strain curve, UTS, YP, Hooke's Law, Experiment on determining Shear Str of Mild and TMT Steel on UTM, Experiment on determining Torsional Str of Mild Steel Bar using TTM, Truss analysis With force calculation.

3. **Unit III : Fundamentals of Thermodynamics -** Zeroth Law of Thermodynamics & First Law of Thermodynamics, Second Law of Thermodynamics, Clausius statement & Kelvin Plank statement and their equivalence, PMM, Concept of Reversibility & Reversible cycle, Entropy, Entropy as property, Clausius inequality, Principle of increase of Entropy ,Ideal gas properties & processes: Gas Laws, Equation of state, Specific and Universal Gas Constant ,Ideal gas processes: P- V & T-S diagrams, Constant Pressure, Volume, Isothermal, Adiabatic, Polytropic & Throttling Processes, Measuring Co-efficient of Performance (COP) in Refrigeration system, Gas Power Cycles & Vapour Power Cycles, Experiment on Single Stage Reciprocating Air Compressor, principles of heat transfer.

4. **Unit IV : Fundamentals of Metallurgical Engineering -** Recovery, Re-crystallization, Grain Growth, Creep and Super-plasticity ,Effect of Alloying Elements in Steel, Microstructure, properties and Defense Application of Plain Carbon Steel, Low Alloy Steel, Maraging Steel, Stainless Steel and Cast Iron, Properties and Defence Use of Cu Alloys, aluminum alloys as ordnance materials, Study of Micro Structure of CI, Steel and Non-Ferrous Metals using Optical Microscope, Measurement of Hardness of Steel with Thickness less than 5mm using Vickers Hardness Tester, Measurement of Hardness of Steel of thickness more than 5mm using Brinell Hardness Tester, Measurement of Toughness of Steel using Impact Testing Machine, Heat treatment on steel, Powder metallurgy.

4. **Unit IV : Fundamentals Of Hydraulics -** Fluid Mechanics: Hydrostatic forces on submerged plane surfaces, buoyancy and stability. Bernoulli equation & its applications, energy equation for flow systems, Laminar and turbulent flows in pipes, Hydraulics: Pumps, Types, Classification, working principles, Selection of pumps, Actuators: Types & application, Hydraulic Circuits: Simple reciprocating, regenerative, Speed control, sequencing, automatic reciprocating, counter balance, Unloading circuits, Pneumatics: Laws of compression, Types of compressors, Filters, regulators, Lubricators, Mufflers and dryers, Pressure regulating valves, direction control valve.

5. **Unit V : Fundamentals of Engineering Drawing -** Intro to Engineering Drawing, Lettering & Dimensioning Practices & Scale, Theory on Geometric, Isometric and Orthographic Construction, Intro to CAD/CAM, Creation, modification & optimisation of design and Auto CAD.

Course Outcomes
Basic knowledge of Electronic & Communication, Mechanics, Thermodynamics, Metallurgical Engineering, Hydraulics and Engineering Drawing helps officers
Text Books
Fundamentals of Electronic Communications Systems
Reference Books Fundamentals of Applied Mechanics by D. R. Malhotra, Thomas P. Olivo Fundamentals of Thermodynamics by Claus Borgnakke, Richard Edwin Sonntag Fundamentals of Metallurgy by S Seetharaman Fundamentals of Hydraulic Engineering by Alan L. Prasuhn Fundamentals of Engineering Drawing by R. K. Dhawan

Course Code	Course Name	L – T – P	**Credits**
TTC 504	**Fundamental of Armament Technology**	3-1-0	**4**
Course Objectives: To impart fundamental knowledge in the fields of Armament Technology and Nuclear Science & Weapon			

Course Contents

1. **Unit I : Basics of Armament Technology (SA & Canons) -** Principle of Operation Automatic Weapons- Blowback Operation, Recoil & Gas Op, Basic problems of Blowback design, Method of recording accuracy, FOM method, Standard deviation method, Average diagonal method, Hit – Efficiency of bullet, carrying power of bullet, Chances of hit : Efficiency of bullet, carrying power of bullet, stability coefficient, capacity of penetration, vertex height, Accuracy and Consistency: Methods of recording accuracy, muzzle mov and factors affecting muzzle mov, Factor affecting chances of hit: Recoil in wpn, measurement of recoil, recoil impulse, muzzle movement cycle of operation, Trigger Mech and Firing Mech- Design characteristics and reqmts, Types of Recoil system & Factors affecting recoil Op, Gas Op: Basic principles, types of gas operated systems, control of op energy, Variable gas track, and Variable expansion sys. Extraction and Safety Device.

2. **Unit II : Nuclear Science & Weapons -** Fission And Fusion As Nuclear Reactions And Energy Release: Nuclear fission, nuclear protection against thermal radiation, first, second and third degree bums, nuclear radiation (neutron and gamma), Enhanced radiation weapon (Neutron bomb),Its advantages and disadvantages over other nuclear weapons, Radiation effects on various targets and protective measures against them, Formation of EMP, its characteristics and damage potential against electronics equipment's/ communication network, Chemical and Biological weapons – their properties, classification, effects and protective measures specific to AFVs.

Course Outcomes
Integration of Armament Technology and Nuclear Science & Weapon helps officer towards basic knowledge and its impact
Text Books
Handbook Of Military Science and Armament Technology by R. K. Jasbir Singh
Reference Books
Introduction to Battlefield Weapons Systems and Technology by R. Geoffrey Lee Introduction to Nuclear Science by Jeff C. Bryan

Course Code	Course Name	L – T – P	**Credits**
TTC 505	**Advance Science & Technology - I**	3-1-0	**4**

Course Objectives: To impart fundamental knowledge in the fields of AI Technology, Cloud Computing & IoT Technology, 3D Printing Technology and Data Analysis

Course Contents

1. **Unit I: Fundamentals of AI Technology-** Fundamentals of AI,ML & Deep Learning, Brief on Supervised, semi-supervised & reinforcement learning, Brief on Neural Network & Machine Learning Implementation, Mil Appl of AI and latest R&D

2. **Unit II: Fundamentals of Cloud Computing & IoT Technology -** Concept and type of cloud computing, Latest commercial and mil appln, Concept & IoT enabling tech, IoT Architecture & Maj Components (Software & Hardware), Brief on IoT Comn and Network protocols, Latest trend and application of IoT including military applications globally.

3. **Unit III: Fundamentals of 3D Printing Technology -** Intro to 3D printing and its enabling tech, Types and various application of 3D printing techniques, aspects of quality control including industrial practices for Metal 3D printing, Latest trends in 3D printing manufacturing including military application of 3D printing technology.

4. **Unit IV: Fundamentals of Data Analysis -** Intro to Linear Regression analysis, measuring of error & estimating the coefficients, Basis of predictive analysis & case studies, Intro to concept of Big data analysis, Brief on Hadoop, Hive and Spark theory.

Course Outcomes

Integrated fundamental knowledge of AI Technology, Cloud Computing & IoT Technology, 3D Printing Technology and Data Analysis

Text Books

Fundamentals of Artificial Intelligence - An Advanced Course by Philippe Jorrand, W. Bibel

Reference Books
Edge Computing Fundamentals, Advances and Applications by K. Anitha Kumari, G. Sudha Sadasivam, D. Dharani, M. Niranjanamurthy Fundamentals of 3D Food Printing and Applications by Bhesh Bhandari, Fernanda C. Godoi, Min Zhang, Sangeeta Prakash Fundamentals of Data Analytics With a View to Machine Learning by Rudolf Mathar, Gholamreza Alirezaei, Emilio Balda, Arash Behboodi ·

DETAILED SYLLABUS OF SEMESTER -II

Course Code	Course Name	L – T – P	**Credits**
TTC 506	**Basic Science & Technology - II**	3-1-0	**4**
Course Objectives: To impart fundamental knowledge in the fields of Electrical Engineering, Lasers & Electro Optic, Workshop Technology and Mathematics & Reliability Engineering			

Course Contents

1. **Unit I: Fundamentals of Electrical Engineering -** Jules law, Thermal efficiency, quantity of electric charge, Flux density, Magnetic Induction, Permeability, Force on a current carrying conductor laying in magnetic field ,Magnetizing force of a long straight conductor, long solenoid, force between two parallel conductors , Electromagnetic Induction, Static and Dynamically induced EMF, Self-inductance, and Mutual inductance, Magnetic hysteresis, DC Generator: Principle, construction, armature winding and resistance, types of generators- series wound, shunt wound and compound generator. DC Machine: Construction, Working, Principle, Theory of generator, Electric Motors, brief description and type of energy transfer and Type of motors.
2. **Unit II: Fundamentals of Lasers & Electro Optics -** Laser System: Classification of lasers, Principles of Op, Type of lasers incl solid state, dye, gas, semiconductor, Laser applications including military , Fiber optics & applications, Optical phenomena, Snell's law of refractive index, Total internal reflection, numerical aperture, Types of fibres and its applications, Electro – optics devices, Basics of electro optics, Classification of combat Imaging Technologies and their components including in AVFs, Thermal Imaging technologies , TI components and Future trends including for AFVs.
3. **Unit III: Fundamentals of Workshop Technology -** Welding Weldability, classification of welding electrodes, fluxes and requirement of inert atmosphere, polarity of welding, latest trends, Practical on welding jobs Introduction of Welding, Defects, Joint preparation, Weld symbol, Types of welding, practical on arc welding, Foundry, Moulding processes, special casting processes, Pattern types, Defects, Lathe Types of lathe, main parts of lathe and its functions including practicals , Milling operation, parts of milling machine, Gear cutting and method of indexing theory followed by practical.
4. **Unit IV: Mathematics & Reliability Engineering -** Introduction to Differential & Integral Calculus, Statistics - Measure of Central Tendency, Measure of Variation, Introduction to Probability, Conditional probability, Binominal Distribution, Poisson

Distribution, Normal Distribution, Reliability estimation, Prediction of System Reliability, Mission Reliability, Failure Mode and Effect Analysis (FEMA), Strategies for Failure Risk Management and Case Studies.
Course Outcomes
Integrated fundamental knowledge of Electrical Engineering, Lasers & Electro Optic, Workshop Technology and Mathematics & Reliability Engineering
Text Books
Workshop Technology by RS Khurmi | JK Gupta
Reference Books
Fundamentals of Electrical Engineering by Rajendra Prasad Lasers and Optoelectronics Fundamentals, Devices and Applications by Anil K. Maini Workshop Technology by Ravindra Prakash Kiran Reliability Engineering Methods and Applications by Mangey Ram

Course Code	Course Name	L – T – P	**Credits**
TTC 507	**Military Autonomous System**	3-1-0	**4**
Course Objectives: To impart fundamental knowledge in the fields of Simulation, Elementary Robotics and Autonomous Unmanned Ground Vehicle Systems			
Course Contents 1. **Unit I: Fundamentals of Simulation -** Basics of Simulation, modelling ,Handling Stepped and Event-based Time in Simulations, Discrete vs Continuous modelling, numerical techniques, Sources and Propagation of Error Including current research and military applications . 2. **Unit II: Elementary Robotics -** Overview of robotics in practice and research including vision, Motion planning, mobile mechanisms, basic kinematics and sensors, Physical project execution on construction of simple microcontroller-based-robots, reinforcing the basic principles developed in lectures, Expose students to some of the contemporary happenings in robotics, incl current research & military applications. 3. **Unit III: Introduction to Autonomous Unmanned Ground Vehicle Systems -** Intro to autonomous sys and vehicles, Hardware and software stack for autonomous vehicles, Perception, localisation, planning and control, Latest trends in commercial and mil applications, Global scan of UGV sys and R&D in India.			
Course Outcomes			
Integrated fundamental knowledge of Simulation, Elementary Robotics and Autonomous Unmanned Ground Vehicle Systems			
Selected Text Books			
Killer Robots: Legality and Ethicality of Autonomous Weapons by Armin Krishnan			
Reference Books			

Modeling and Simulation Fundamentals Theoretical Underpinnings and Practical Domains by John A. Sokolowski, Catherine M. Banks Elementary Robotics by John Heffernan Unmanned Aerial Vehicles - An Introduction by P. K. Garg

Course Code	Course Name	L – T – P	**Credits**
TTC 508	**Armoured Fighting Vehicle Armament Technology**	3-1-0	**4**
Course Objectives: To impart fundamental knowledge in the fields of Armoured Fighting Vehicle Technology, Tank Weapon and Armour, Missile Technology, Tank Design Parameters and Military Ballistics			

Course Contents

1. **Unit I: Fundamentals Of Armoured Fighting Vehicle Technology -** AFV Fire Power : Characteristics of fire power, Probability of Kill, Fire Control system, Latest Trends in Fire Power, AFV Mobility : Characteristics of mobility, mobility parameters, Obstacle crossing ability including fording / floatation, navigation to include GPS and GLNS. Soil Mechanics, Soil vehicle interaction and terrain evaluation, electrical transmission, AFV Protection : Active Protection Systems, Indirect protection, NBC and Fire Protection System , Maintainability, availability and ergonomics , Analysis of AFV designs and development, review of World MBTs, Indian Scenario to include Tank T-72, T-90 and MBT Arjun, ICV BMP-2 and variants, Light and wheeled Vehicles, Bridge Laying Tanks and Trawl Tanks ,Futuristic Combat system with emphasis on tank platform.
2. **Unit II: Fundamentals Of Tank Weapon and Armour -** Tank gun mountings and mounting problems - Externally mounted guns, Stability of guns, factors affecting stability of guns, Auto loaders, Stability of Firing Platform, Electromagnetic guns, Electro-thermal guns, latest trend in gun designing like liquid propellant guns, rail gun, KE shot- Armr reactions, Internal, External and terminal ballistics, universal shot armr formula, failure of armr & shot, Breech Mechanism: QF type and BL type, breech rings; firing mechanism; percussion and electrical types, Recoil systems: Types of recoil systems, latest development in recoil sys, Effect of recoil sys in designing of tanks, fume extractors; muzzle brakes; balancing gears and balancing weights, thermal shields, modern trends in tank ,Explosives : Introduction to Explosives, types of expls and capability to defeat armour, latest trends.
3. **Unit III: Fundamentals Of Missile Technology** - Missile Propulsion: Introduction and classification of propulsion systems, solid rocket and liquid rocket, advances in propulsion system, Missile Aerodynamics: Introduction to missile aerodynamics, general aerodynamic design considerations, aerodynamic forces and moments, various missile configurations, Missile Guidance: Need for Guidance System, Various types of Guidance Systems used in mid phase and terminal phase of missiles. Introduction to command, beam rider horning and

IR guidance system, Missile Control: Introduction to Missile control, polar and Cartesian control, aerodynamic and thrust vector control. 3. **Unit IV: Fundamentals of Tank Design Parameters** - Concept and brief introduction to design parameters, basic dimension, factor wrt weight, height & width, Turret Design, Steerability, pitch ratio, Power to weight ratio, NGP and MMP, Track width and weight analysis, Parametric Design Study, Future Tk design and armament 4. **Unit IV: Fundamentals of Military Ballistics -** Overview , Internal ballistics, Transitional ballistics, External ballistics, Terminal ballistics, Challenge of ballistics in weapon and ammunition design,Latest trends.
Course Outcomes
Integrated fundamental knowledge of Armoured Fighting Vehicle Technology, Tank Weapon and Armour, Missile Technology, Tank Design Parameters and Military Ballistics
Text Books
Armoured Fighting Vehicle Technological Evolution and Tactical Impact in Modern Warfare by Fouad Sabry
Reference Books
Armored Fighting Vehicles by Philip Trewhitt Tank Gun Systems by William Andrews Fundamentals of Advanced Missiles by Richard B. Dow Fundamentals of Tank and Process Equipment Design by András Nagy Military Ballistics by G. M. Moss, D. W. Leeming, C. L. Farrar

Course Code	Course Name	L – T – P	**Credits**
TTC 509	**Armourd Fighting Vehicle Propulsion Technology**	3-1-0	**4**
Course Objectives: To impart knowledge in the fields of Tank Propulsion Technology and Tank Power Plant Technology			
Course Contents 1. **Unit I : Tank Propulsion Technology** - Suspension: Introduction to suspension in military vehicles, types of suspension, including spring and dampers, Variable rate springs, tank suspension including T-72, T-90 and MBT Arjun. Future trends, Introduction to txn in military vehicles, type of Transmission system, transmission sys in wheeled vehicle including automatic transmission and CVT, transmission in various tanks including:T-90 and MBT Arjun, Gear Box : Evolution of various tops of gear boxes, Resistance to motion, requirement of gear box, Gear ratios, EPI-cyclic gear trains, Vehicle Performance curves, Steering: Introduction to steering principle and requirement, Steering Geometry, Steering mechanism to wheeled vehicles, Power steering and planetary steering mechanism system, tracked vehs with emphasis on T-72,T-90 and MBT-ARJUN ,Brakes: Principle, requirements & brakes in wheeled vehicles, Power brakes, Braking systems in T-90 and, T-72 and MBT-ARJUN.			

2. **Unit II: Tank Power Plant Technology -** Description of eng components: Air standard cycles & Fuel air cycles: assumptions, Otto, Diesel & Dual cycles, Comparison of cycles, Fuel air cycles, Valve timing diagram, actual engine cycle, SI Engine: Theory of carburetion, type of carburettor, electrical fuel injection sys. Combustion in SI engine, stage of combustion, flame propagation, abnormal combustion, phenomenon of detonation & effect on engine, combustion chamber rating of fuel in SI engines, Cl Engines: Fuel supply system, types of fuel pump, injection and distribution system, combustion in CI engine stage at combustion& factors affecting combustion, Phenomenon of knocking and its effects, comparison of knocking in SI & Cl engines, types of combustion chambers. Fuel ratings, comparison of knocking in SI & CI engine, VCR engines: Hyper bar engine, Dual and Multi fuel Engines. Gas Turbine – classification, Joule or Brayton cycle efficiency, regenerative and reheat gas turbine cycle. Stratified charged engines- general characteristics & methods. Application, advantage & disadvantage, Fuel & Emission of IC engine emission control method for SI & CI engines. Brief on hybrid vehicles.
Course Outcomes
Integrated knowledge of Tank Propulsion Technology and Tank Power Plant Technology
Text Books
Vehicle Propulsion Systems: Introduction to Modeling and Optimization by L. Guzzella, Antonio Sciarretta
Reference Books
Armored Fighting Vehicles by Philip Trewhitt Fundamentals of Tank and Process Equipment Design by András Nagy

Course Code	Course Name	L – T – P	**Credits**
TTC 510	**Advance Science & Technology - II**	3-1-0	**4**
Course Objectives: To impart fundamental knowledge in the fields of Battled Field Environment, EMI/EMC, Nano Tech & Military Application, Quantum Technology and Science of Equipment Management During Peace and War			
Course Contents 1. **Unit I : Integrated Battled Field Environment** - C4ISR system of Digitized Battle Fd environment, Integration of sensor & shooter link, Battle Field Management System (BMS), Sensors and Surveillance systems, Digital Battle Field Environment, ISR Architecture & Comn Perspective, Integrated Communication Tactical Battle Field Area, Electronic Warfare : Org, Role, Capb in Mech Ops. 2. **Unit II – Fundamentals of EMI/EMC -** Basics of EMI/EMC, Mitigations Techniques, Case Studies on AFVs and Compliance testing. 3. **Unit III – Fundamentals of Nano Tech & Mil Appl -** Elements of Nanoscience and Nanotechnology, Properties and production of Nano materials, Industrial and military application of nanoscience and materials.			

4. **Unit IV – Fundamentals of Quantum Technology** - Brief intro to quantum theory, Exploitation of quantum tech in computing and communications, Latest trends and mil application of quantum technology. 5. **Unit V – Science of Equipment Management During Peace and War -** Basics function of EM, Concept of eqpt life cycle, Integrated logistic support & life cycle costing, Org & role of MoD, MGO Br in equipment management, Technology transition management and product improvement at Army level , Sustainment Engineering & Operational Sustainment, Equipment Readiness , Mission Reliability, Ex Haunsla.
Course Outcomes
Integrated fundamental knowledge of Battled Field Environment, EMI/EMC, Nano Tech & Military Application, Quantum Technology and Science of Equipment Management During Peace and War
Text Books
Recent Advances in Applied Science and Engineering by Dr. Ankita Saini, Dr.Sunil Kumar Saini
Reference Books
The Integrated Battlefield Control System, by Edward P. Smith Fundamentals of Electromagnetic Compatibility by William G. Duff Nanotechnology for Defence Applications by Narendra Kumar, Ambesh Dixit Fundamentals of Quantum Optics and Quantum Information by Peter Lambropoulos, David Petrosyan

DETAILED SYLLABUS OF SEMESTER -III

Course Code	Course Name	L – T – P	**Credits**
TTC 511	**Combat Power Application: Doctrine**	-	**4**
Course Objectives: To impart fundamental knowledge in the fields of Infusion of Drone Technology in Various Operations and Doctrine and Operations			
Course Contents 1. **Unit I – Infusion of Drone Technology in Various Operations -** Intro to Drone Systems, Categorisation, Basic Principles of Flight, System Architecture & Components, Intro to Video/ Image interpretation & Basics Aerial Imaging , Calibration, Pre Flight and Post Flight Checks, Analysis of Faults and Diagnosis and application in ops of war, Counter Drone Tech incl Active and Passive Sys and Measures, simulator practical . 2 . **Unit II – Doctrine and Operations -** Org and emp doctrine of Armd Figting Vehicles including Tanks and ICVs, Operations in various terrain, criticalities, challenges, en 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.			
Course Outcomes			

Integrated fundamental knowledge of Infusion of Drone Technology in Various Operations and Doctrine and Operations
Text Books
Combat Power: An Ontological Approach by John G. Heslin
Reference Books
Exploring the Skies: A Comprehensive Guide to Drone Technology by Charles Nehme

Course Code	Course Name	L – T – P	**Credits**
TTC 512	**Combat Power Application: Operations**	-	**4**
Course Objectives: To impart fundamental knowledge in the fields of Land Operation, Conduct of Lad Operations and New Generation Warfare			
Course Contents 1. **Unit I – Fundamentals of Land Operations –** Intro 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, sandmodel, computer simulations and field operations. 3. **Unit III – New Generation Warfare –** Intro and familiarisation of new generation of warfare in global conflicts and disruption of technology & challenges and methods to adopt it.			
Course Outcomes			
Integrated fundamental knowledge of Land Operation, Conduct of Land Operations and New Generation Warfare			
Text Books			
Combat Power in Domestic Operations by Kyle G. Ferlemann			
Reference Books			
Electronic Warfare: Element of Strategy and Multiplier of Combat Power by Don Edward Gordon			

Course Code	Course Name	L – T – P	**Credits**
TTC 513	Combat Power Application: SD Aspects	-	**4**
Course Objectives: to understand fundamental principles of combat power application with staff duties in the field			

Course Contents 1. **Unit I : Intro to SD –** Fundamentals of staff duties to include all procedure and methods towards optmising operations**.** **2. Unit II : SD Apsects in Field –** Understand and practise all SD aspects related to planning, preparation and conduct of operations including exercise.
Course Outcomes
Integrated fundamental knowledge of staff duties in the field
Text Books
Services Chiefs of India by S. Sartaj Alam Abidi, Satinder Sharma ·
Reference Books
Services Chiefs of India by S. Sartaj Alam Abidi, Satinder Sharma ·

Course Code	Course Name	L – T – P	**Credits**
TTC 514	**Syndicate Technical Projects**	-	**8**
1. **Syndicate Technical Projects -** The students will present their written project work on Problem Statements which will included technological solutions as well as recommended changes to TTPs for enhancing operational effectiveness. The assessment will be internal by a nominated Borad of Officers detailed from the Instructional Faculty of Armd Corps Centre and School.			

Course Code	Course Name	L – T – P	**Credits**
TTC 515	**Dissertation**	-	**16**
Course Objectives:			
1. **Dissertation –** The students officers will submit their dissertation on given project based on Technical Problem Statement received from the environment including field army organisation. The dissertation will be submitted to School of Defence Technology, DIAT in the fourth semester for assessment and award of MSc Degree in Tank Technology.			

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
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 2013
10. How to Read an Engineering Research Paper by William Griswold. UC at San Diago

11. How to Write an Effective Literature Review by Sonia Martinez, University of California 12. 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

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, 2nd 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.

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.

Course Contents

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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.

Text & Reference Books

13. Research Methodology: An Introduction by C. R. Kothari, New Age International Publishers
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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
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 2013
22. How to Read an Engineering Research Paper by William Griswold. UC at San Diago
23. How to Write an Effective Literature Review by Sonia Martinez, University of California
24. How to write a research journal article in Engineering and science by Scott A. Socolofsky