COURSES OF STUDY
FOR
POST GRADUATE PROGRAMMES

(2022 – 2024)

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

CONTENTS

1. M.Tech Programs for the Academic Batch 2022-24

2. MASTER OF SCIENCE (M.Sc.) PROGRAM and PG Diploma PROGRAM

NOTE: *Robotics is a multidisciplinary specialization, M.Tech degree will be awarded as per the UG Degree of the student viz. M.Tech in EE/ME/AE etc.

Sponsored (DRDO/Tri Services/DPSUs/PSUs/Industry) only.

$ Applicable for sponsored/self sponsored candidates only.

@ Applicable for MoD sponsored candidates only.

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 makes 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 2022-23(ODD SEMESTER)

(AUG 2022 –DEC 2022)

Sl. No.	Activity	Dates
1.	Registration (M. Tech. / MS (by Research)/ MSc/ PGD/ Ph. D) Re-examination for Even semester courses Add/Drop Courses & Finalizing Electives and Orientation Programme	**1st Aug – 8th Aug 2022** **(PG 1st Year)** **11th July 2022-18th July 2022 (PG 2nd Year)**
2.	Last date of Late Registration with late fee	**26th Aug 2022**
3.	Sending Certified list of courses (Regular, Self study, Audit etc) registered by the students - by Jt. Reg. (ACs) to COE	**30th Sep 2022**
4.	Classes including Preparation	**1st Aug – 9th Dec. 2022** **(19 weeks) for 1st year**
5.	Project Work-2nd Year	**11th July -9th Dec. 2022**
6.	PhD progress review by DRMC	**11th July – 29th July 2022**
7.	Sending the Panel of Examiners to COE	**30th Sep. 2022**
8.	Last date of submission of Examination form and Admit Card to COE by the Students.	**21st Oct. 2022**
9.	End Semester Examination	**12th Dec – 27th Dec 2022**
10.	Oral Examination Committee approved by Vice- Chancellor to be sent to COE (Thesis first Phase evaluation)	**18th Nov 2022**
11.	Seminar Presentation & Evaluation / Practical Examination (M.Tech. 1st Sem) / Thesis first evaluation (M.Tech. 3rd Sem) / PhD progress review by DRMC	**12th Dec – 23rd Dec. 2022**
12.	Last date for submission of certified Statement of Marks to COE (Courses / Seminar / Lab / Thesis)	**30th Dec 2022**
13.	Winter Vacation For Faculty and Students	**2nd Jan. 2023 – 15th Jan 2023 (2 Weeks)**
14.	Result Declaration – Autumn Semester	**16th Jan. 2023**
15.	Outstation Instructional Tour (Optional)	During the period provided for classes without affecting any academic activities.

Note:

1. The Classes may be conducted Online/Offline (Class Roorn) or Blended mode (Onlinc + offline) following the prescribed protocols / guideline related to pandemic.
2. The Academic calendar may change subject to the conditions due to pandemic and guidelines issued by the Ministry of Health, Ministry of Home & Ministry of Education from time to time.

ACADEMIC CALENDAR 2022-23 (EVEN SEMESTER)

(Jan. 2023 – June 2023)

Sl. No.	Activity	Dates
1	Registration (M. Tech. / MS (by Research)/ MSc/ PGD/ Ph. D) Re-examination for Odd semester courses Add/Drop Courses & Finalizing Electives and Orientation Programme	16th Jan. – 20th Jan 2023
2.	Last date of Late Registration with late fee	17th Feb. 2023
3.	Sending Certified list of courses (Regular, Self study, Audit etc) registered by the students – by Jt. Reg. (Acs) to COE	10th Mar. 2023
4.	**Classes (Phase I)**	16th Jan – 24th Mar. 2023 **(10 weeks)**
5.	**Sport/Cultural/NSS/Other student related activities**	**27th Mar -31st Mar. 2023 (1 week)**
6.	**Classes (Phase II) including Preparation**	3rd April -27th May 2023 **(8 Weeks)**
7.	PhD progress review by DRMC	16th Jan. – 27th Jan. 2023
8. 9.	Sending the Panel of Examiners to COE	10th Mar. 2023
10.	Last date of submission of Examination form and Admit Card to COE by the Students.	14th April 2023
11.	End Semester Examination	29th May – 13th June 2023
12.	Oral Examination Committee approved by Vice- Chancellor to be sent to COE(Thesis first Phase evaluation)	21st April 2023
13.	Seminar Presentation & Evaluation / Practical Examination (M.Tech. 2nd Sem) / Thesis first evaluation (M.Tech. 4th Sem) / PhD progress review by DRMC	29th May – 9th June 2023
14.	Last date for submission of certified Statement of Marks to COE (Courses / Seminar / Lab / Thesis)	16th June 2023
.15.	Summer Vacation For Faculty and Students	19th June– 16th July 2023 (4 weeks)
16	Result Declaration – Even Semester	17th July 2023
17	Outstation Instructional Tour (Optional)	During the period provided for classes without affecting any academic activities

Note:

1. The Classes may be conducted Online/Offline (Class Roorn) or Blended mode (Onlinc + offline) following the prescribed protocols / guideline related to pandemic.
2. The Academic calendar may change subject to the conditions due to pandemic and guidelines issued by the Ministry of Health, Ministry of Home & Ministry of Education from time to time.

Programmes Structure

&

Syllabus of Courses

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 Air Armaments & 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:

- Flight Guidance and Control, Robust and Nonlinear Control
- Flight Dynamics and Trajectory Optimization
- Experimental Aerodynamics
- Aero-elasticity
- Flow Control
- UAV Design

Currently, the department offers M.Tech. in Aerospace Engineering with three specializations namely Guided Missiles, UAVs and Air Armaments. The details of the programmes are given below:

M. Tech. in Aerospace Engineering (Guided Missiles)

Brief Description: The department has been involved in conducting post-graduate programme in Aerospace Engineering with specialization in Guided Missiles Technology. This programme consists of courses in areas of aerospace engineering with relevance to guided missiles. Curriculum of the programme 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 programme 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 programme will be of four-semester duration. In the first semester there are six courses. In the second semester there are six 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.

The details of the courses offered under the programme are given below:

M. Tech. in Aerospace Engineering (Guided Missiles)

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 604	Aerospace Structures	3	1	4
6	AE 605	Flight Mechanics	3	1	4
		Total	**18**	**6**	**24**

Semester II

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	AE 606	Flight Instrumentation	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
		Total	**18**	**6**	**24**

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

Semester III

		Course	Credits	Total

Sl. No.	Course Code		L	T/P	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 Mechanic
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
		Open electives from other Departments

M. Tech. in Aerospace Engineering (UAVs)

Brief Description: This programme 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/ Electronics/ Electrical/ Electronics and Communication from recognized university.

Organization: The programme will be of four-semester duration. In the first semester there are six courses. In the second semester there are six 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.

The details of the courses offered under the programme are given below:

M. Tech. in Aerospace Engineering (UAVs)

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 604	Aerospace Structures	3	1	4
6	AE 605	Flight Mechanics	3	1	4
		Total	**18**	**6**	**24**

Semester II

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	AE 606	Flight Instrumentation	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
		Total	**18**	**6**	**24**

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 Mechanic
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
		Open electives from other Departments

M.Tech. in Aerospace Engineering (Air Armaments)

Brief Description: The aim of the program is to impart advanced training and to update knowledge in the field of design, development, quality assurance and Inspection of air armaments to engineering officers from Air Force, Army, Navy & DRDO. At the end of the program the officer should be able to undertake R&D work and/or inspection, testing and evaluation of armament systems.

Eligibility: Bachelor's Degree in Aerospace, Aeronautical/Mechanical Engineering of a recognized Institute/University.

Organization: The programme will be of four-semester duration. In the first semester there are six courses. In the second semester there are six 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.

The details of the courses offered under the programme are given below:

M.Tech. in Aerospace Engineering (Air Armaments)

Semester I

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	AM 607	Mathematics for Engineers	3	1	4
2	AFW 601	Ballistics of Bombs & Projectiles	3	1	4
3	AFW 602	Design of Air Armament - I	3	1	4
4	AE 601	Aerospace Propulsion	3	1	4
5	AE 602	Aerodynamics	3	1	4
6	AE 605	Flight Mechanics	3	1	4
		Total	**18**	**6**	**24**

Semester II

Sl. No.	Course Code	Course	Credits		Total Credits (*)
			L	T/P	
1	AFW 603	Airborne Weapon System Effectiveness	3	1	4
2	AFW 604	Warhead Design and Mechanics	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
		Total	**18**	**6**	**24**

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

Semester III

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

****Contact Hours/week**

List of Electives

Sl. No.	Course Code	Course
1	AFW 605	Air Armaments Control and Guidance
2	AFW 606	Design of Air Armament - II
3	AFW 607	Testing and Certification of Air Armament Stores
4	AFW 608	Fire Control Systems
5	AE 604	Aerospace Structures
6	AE 606	Flight Instrumentation
7	AE 607	Missile Propulsion
8	AE 608	UAV Design
9	AE 609	Guidance & Control for Aerospace Vehicles
10	AE 610	Missile Guidance & Control
11	AE 611	UAV Guidance & Control
12	AE 612	Experimental Aerodynamics
13	AE 613	Computational Aerodynamics
14	AE 614	Structural Dynamics and Aero-elasticity
15	AE 615	Estimation and Tracking for Aerospace Applications
16	AE 616	Nonlinear and Robust Control
17	AE 617	Avionics
18	AE 618	Robotic Control
19	AE 619	Signals and Systems
20	AE 620	Optimal Control with Aerospace Applications
21	AE 621	Advanced missile guidance
22	AE 622	Ducted Rocket & Combustion
16	AE 623	Experimental Methods in Fluid Mechanic
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
		Open electives from other Departments

AE 601 Aerospace Propulsion

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

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.

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)

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

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

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

References

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
5. Gordon C Oates, "Aerothermodynamics of Gas Turbine and Rocket Propulsion" 3rd Edition, AIAA Education,
6. Maurice J Zucrow , "Aircraft and Missile Propulsion", Vol 1 & 2, Wiley

AE 602 Aerodynamics

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.

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 flow.
Aerodynamic characteristics of aerospace vehicles.
Introduction to experimental aerodynamics.

Text/References:

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.
4. F. M. White, Viscous Fluid Flow, McGraw Hill, 2006.
5. F. M. White, Fluid Mechanics, McGraw Hill, 2003.
6. Fox and MacDonald, Introduction to Fluid Mechanics, 5th Edition, John Wiley & Sons, inc, 2003.
7. John D. Anderson, Modern Compressible Flow: With Historical Perspective, 3rd Ed, McGraw Hill, 2004.
8. John D. Anderson, Hypersonic and High Temperature Gas Dynamics, McGraw Hill, 2006.

9. Maurice Rasmussen, Hypersonic Flow, John Wiley & Sons, inc, 1994.
10. S. S. Chin, Missile Configuration Design, McGraw Hill, 1961.
11. **Michael R. Mendenhall**, Tactical Missile Aerodynamics,2nd Ed., AIAA Publications, 1992.
12. Reg Austin, Unmanned aircraft Systems: Uavs design, development and deployment, John Wiley & Sons, inc, 2010.

AE 603 Navigation, Guidance & Control

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.

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.

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.

Texts/References:

1. Ching Fang Lin, Modern Navigation, Guidance and Control Processing, Prentice Hall, 1991
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. Anthony Lawrence, Modern Inertial Technology, Springer, 1998
   K. Ogata, Modern Control Engineering, Prentice Hall of India, 1995.

AE 604 Aerospace Structures

Review of Strength of Materials.

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

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

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

Analysis of stress; Analysis of strain.

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

Introduction to Vibration and Fatigue.

Texts/ References:

1. David J. Peery, Aircraft Structures, Dover Publications, 2011
2. E. F. Bruhn, Analysis and Design of Flight Vehicle Structures, S.R. Jacobs, 1973
3. T. H. G. Megson, Aircraft Structures for Engineering Students, Butterworth-Heinemann, 2010.
4. G. F. Titterton, Aircraft Materials and Processes, Himalayan Books, 2013.

AE 605 Flight Mechanics

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.

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.

Text/References:

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.

Suggested References:

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.

AE 606 Flight Instrumentation

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.

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

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.

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

Texts/References:

1. E.O. Doebelin, Measurement Systems: Application and Design, 4thEd, McGraw Hill International, New York, 1990
2. J.M. Lloyd, Thermal imaging system, Plenum Pub., New York, 1975
3. D. Patranabis, Telemetry Principles, Tata McGraw Hill, New York, 2000.

AE 607 Missile Propulsion

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

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.

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.

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)

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

Text/References:

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

AE 608 UAV Design

Terminology. Requirements. Certification approaches: aircrafts and UAVs. Airworthiness of aircrafts and UAVs. Airsafety issues. Handling qualities. Maneuverability requirements.

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.

Introduction to UAV system Development.

Text books:

1. Daniel P. Raymer, Aircraft Design: A Conceptual Approach. AIAA Education Series, 2012
2. J. Jayaraman, Unmanned Aircraft Systems: A Global View, DRDO, 2014.
3. Reg Austin, Unmanned Aircraft Systems, Wiley Publication, 2010.
4. Eugene L. Fleeman, Missile Design and System Engineering, AIAA Foundation Series, 2014.
5. John Anderson Jr., Aircraft Performance & Design, McGraw-Hill2014.

AE 609 Guidance & Control for Aerospace Vehicles

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

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 auto pilot and roll, lateral autopilot. Modern methods using state space approach, Controllability and Observability. Pole Placement techniques. Introduction to structure control interaction.

Servo Systems: Hydraulic, Pneumatic & electromechanical

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

Text/References:

1. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, New Delhi, 2001.
2. P Zarchan, Tactical and Strategic Missile Guidance, Vol 199 of Progress in Astronautics and Aeronautics, AIAA, Reston, VA, 2002.
3. P. Garnell, Guided Weapon Control Systems, 2nd Ed, Pergamon Press, London, 1980.
4. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, New York, 2004.
5. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.
6. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.

7. Amitava Bose, Somnath Puri, Paritosh Banerjee, Modern Inertial Sensors and Systems, Prentice-Hall of India, 2008.
8. Ian Moir, Allan Seabridge, Malcolm Jukes, Military Avionics Systems, Wiley, 2006.
9. Jay Gundlach, Designing Unmanned Aircraft Systems: A comprehensive Approach, AIAA Education Series, AIAA, 2012.
10. Rafael Yanushevsky, Guidance of Unmanned Aerial Vehicles, CRC Press, 2011.
11. Randal W. Beard and Timothy W. McLain, Small Unmanned Aircraft Theory & Practice, Princeton University Press, 2012.
12. N. V. Kadam, Practical design of flight control systems for launch vehicles and missiles, Allied Publishers, 2009
13. Rasmussen, S., and Shima, T. (Eds.), UAV Cooperative Decision and Control: Challenges and Practical Approaches, SIAM Publications, 2008.

AE 610 Missile Guidance & Control

Missile Kinematics: Kinematics of various courses, time of flight, lateral acceleration demand and turning rate spectrum for each case.

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.

Missile control methods: Aerodynamic and thrust vector control, Polar and Cartesian control

Mathematical modeling: Force and moment equations. Linearization. Transfer function representation of airframe

Missile servo system: Hydraulic, Pneumatic and Electromechanical

Missile instruments: accelerometer, gyroscopes, altimeter, resolvers

Autopilot design based on classical approach: Roll stabilization. Lateral autopilots based on various combinations of rate gyro and accelerometer feedbacks. Three loop autopilot.

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.

Text/References:

14. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, New Delhi, 2001.
15. P Zarchan, Tactical and Strategic Missile Guidance, Vol 199 of Progress in Astronautics and Aeronautics, AIAA, Reston, VA, 2002.
16. P. Garnell, Guided Weapon Control Systems, 2nd Ed, Pergamon Press, London, 1980.
17. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, New York, 2004.
18. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.

19. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.

AE 611 UAV Guidance & Control

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
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.

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.

Text/References:

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.
3. Jay Gundlach, Designing Unmanned Aircraft Systems: A comprehensive Approach, AIAA Education Series, AIAA, 2012.
4. Rafael Yanushevsky, Guidance of Unmanned Aerial Vehicles, CRC Press, 2011.
5. J.H. Blakelock, Automatic Control of Aircraft and Missiles, John Wiley, New York, 1991.
6. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.
7. Randal W. Beard and Timothy W. McLain, Small Unmanned Aircraft Theory & Practice, Princeton University Press, 2012.

AE 612 Experimental Aerodynamics

Need and Objectives of Experimental study, Fundamentals of Aerodynamics, Governing equations.

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, shock tubes, atmospheric tunnel, automobile wind tunnel etc., Wind Tunnel Instrumentation & Calibration, Wind tunnel balances.

Pressure Measurements: Manometers, Pressure Probes, Pressure transducers, Pressure sensitive paints.

Velocity measurements: Pressure-based velocity measurements, Hot-wire anemometers (CTA & CCA), Laser Doppler anemometer (LDA), Particle Image Velocimetry (PIV).

Temperature Measurements: Thermocouples, RTD, Temperature sensitive paints, Pyrometers.

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. Measurement of aerodynamic forces and moments.

Specific experimental environments & measurement techniques, flight testing, data acquisition, Data processing, Uncertainty analysis.

Text/References:

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. E. Rathakrishnan, Instrumentation, Measurements and Experiments in Fluids, CRC Press, Taylor & Francis Group, 2009.
5. Doeblin.E.O. Measurement systems Applications and design. 5th ed. McGrawHill, 2003

AE 613 Computational Aerodynamics

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.

Basics of grid generation. Structured grid, unstructured grid

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.

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

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

AE 614 Structural Dynamics and Aero-elasticity

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.

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.

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.

Texts/ References:

1. D. H. Hodges & G. Alvin Pierce, Introduction to Structural Dynamics and Aeroelasticity, Cambridge University Press, 2002
2. Raymond L. Bisplinghoff, Holt Ashley & Robert L. Halfman, Aeroelasticity, Courier Dover Publications, 1996

AE 615 Estimation and Tracking for Aerospace Application

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.

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

• **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.

• **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

Solving the assignment problems using MATLAB tool boxes is mandatory. This proposed course is modification of current elective **AE 615 Estimation with Applications to Tracking and Navigation**

References

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).

AE 616 Nonlinear and Robust Control

Introduction to Nonlinear Systems, Stability analysis, Feedback linearization, Input-State and Input-Output Linearization, Robust Feedback Linearization. Sliding Mode Control and Sliding Mode Observers. 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.

Texts/ References:

1. J.J.E. Slotine and W. Li, Applied Nonlinear Control, Prentice-Hall, NJ, 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 to Implementation, IEE Control Series No. 66, 2004.

AE 617 Avionics

Maps and geodesy; co-ordinate systems and transformations; great circle and rhumb line navigation; dead reckoning; INS-gyroscopes and accelerometers, platform stability and strapped down INS; horizontal and vertical mechanizations in INS; baro-altimeter, air speed indicator, compass and gyro compass; radio navigation - beacons, VOR, DME, LORAN and other nav-aids; primary and secondary surveillance radars; Doppler navigation; 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. Head-Up displays: Helmet mounted displays; Headdown displays. Data fusion. Displays Technology. Control and data entry. Radar and communication FMS. Avionics system integration. Data bus. Introduction to safety systems.

Texts/References:

1. Albert Helfrick, Principles of Avionics, Avionics Communications, 2009
2. Myron Kayton & Walter R. Fried, Avionics Navigation Systems, John Wiley & Sons, 1997.

AE 618 Robotic Path Planning and Control

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 Close Loop Control, The Manipulator Control problem, Linear control Schemes, Characteristics of second order linear systems.

Unit III: Linear Second Order-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.

Textbooks:

1. K. Ogata, Modern Control Engineering, 5th Edition, Prentice Hall, 2010.
2. B. Friedland, Control System Design- An Introduction to State-Space Methods, McGraw-Hill, Singapore, 1987.
3. J.J.E. Slotine and W. Li, Applied Nonlinear Control, Prentice-Hall, NJ, 1991.
4. M. W. Sponge and M. Vidyasagar, Robot Dynamics and Control, John Wiley & Sons, New York, USA, 2004.

AE 619 Signals and Systems

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

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

• 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.

• 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. Solving the assignment problems using MATLAB tool boxes is mandatory.

References

1. Vinay Ingle and John G Proakis: *Digital Signal Processing Using MATLAB* , Congage Learning, Third Edition, (2012).
2. E Oran Brigham: *The Fast Fourier Transform and Its Applications*, Prentice Hall, First Edition, (1988).
3. A V Oppenheim, R W Schafer and John R Buck: *Discrete Time signal Processing*, Prentice Hall, Second Edition, (1999).
4. A V Oppenheim, A S Willsky and S Hamid: *Signals and Systems*, Prentice Hall, Second Edition, (1996).

AE 620 Optimal Control with Aerospace Applications

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

• **Static optimization:** Unconstrained optimization, constrained optimization - Lagrange multiplier, equality constraints, inequality constraints, neighboring optimum solutions. Nu- merical solutions. Linear programming problems. Nonlinear programming, Kuhn Tucker condition, Direct optimization by gradient methods. Solutions of static optimization prob- lems for both constrained and unconstrained case.

• **Optimal control of continuous time system by indirect method:** Optimal control through calculus of variation, EulerLagrange necessary condition, Legendre necessary condi- tion, Jacobi necessary condition, Bolza problem, Mayer problem, Lagrange problem, Some sufficiency conditions to the simplest problem, Transversability conditions, Complete opti- mal 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.

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

• **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.

Solving the assignment problems using MATLAB tool boxes is mandatory.

References:

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).

AE 621 Advanced Missile Guidance

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.

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.

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.

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

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

Text/References

1. P. Garnell, Guided weapon control systems, 2nd ed, pergamon press, London, 1980
2. G.M. Siouris, Missile Guidance and control systems, springer verlag, New Yor, 2004
3. Merill I. Skolnik, Introduction to Radar system, Tata Mc Hill, New Delhi, 2001

AE 622 Ducted Rocket & Combustion

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.

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.

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

Texts/ References:

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
4. I. Glassman, Combustion, Ist Ed, Academic Press, San Diego, California 1997

AE 623 Experimental Methods in Fluid Mechanics

Introduction: Review of concepts of Fluid Mechanics, Introduction to experimental methods, Basic concept of dynamic measurements.

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.

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

Flow visualization: Wool tufts, dyes, smoke wire, smoke rake, smoke tunnel, shadow graph, Schlieren, particles, bubbles, Fluorescence.

Data Acquisition and Processing; Uncertainty Analysis.

Texts/ References:

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

AE 624 Aircraft Assembly, Inspection & Tests

Aerospace manufacturing: A Systems approach and standards, Incoming inspection, documentation, record keeping, identification & traceability, safety in workplace.

Engineering drawing awareness: Basic knowledge of Engg. Drawing: Components & assemblies- Electric, Fuel, Lubrication, Hydraulic, Pneumatic systems and symbols used.

Materials & resources for assembly: Different materials & consumables. Jigs and fixtures, Calibration, Jig less assembly, case studies. Manual vrs automated assembly.

Sub-assembly & Final assembly: Type of fits, Tolerancing , Basics of joining--Welding, Brazing, Soldering & Riveting, Modern joining methods. Set making ,Static & Dynamic Balancing ,Transmission assembly, 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.

Text/References:

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

AE 625 Hypersonic Flow

Introduction: Governing equations and hypersonic relations.

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.

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 Experimental

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

Text/References:

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.

4. John J. Bertin, Russell M. Cummings, Aerodynamics for Engineers, 6 thedition,Prentice Hall, 2013

5. 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

7. Wallace D. Hayes and Ronald F. Probstein, “Hypersonic Flow Theory”, Academic Press Company, 1959

9. Wallace D. Hayes and Ronald F. Probstein, “Hypersonic Inviscid Flow”, Dover Publications,2004

10. W. Hankey, “Re-Entry Aerodynamics”, AIAA education series, 1988

AE 626 Compressible Fluid Flow

Introduction: Review concepts of Aerodynamics, Fluid Mechanics and Thermodynamics

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

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.

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.

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

Text/References:

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, Introductin to transonic aerodynamics: 110 (Fluid Mechanics and Its Applications), Springer, 2015
5. John D. Anderson, Fundamentals of Aerodynamics, 4^{th} Edition, McGraw Hill, 2006.
6. John D. Anderson, Hypersonic and High Temperature Gas Dynamics, McGraw Hill, 2006.

AE 627 Flow Stability and Turbulence

Introduction, Mechanisms of Instability, Fundamental concepts of stability, Stability of parallel shear flow, Stability of free 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, statistical description of turbulence, spectral dynamics, turbulent flow modeling and simulation.

Texts/ References:

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.

3. Henk Tennekes & John Lumley, A First Course in Turbulence, MIT Press (MA), 1972.

4. Stephen B. Pope, Turbulent flow, Cambridge University Press, 2000.

AE 628 Missile Aerodynamics

Introduction to missile airframe, Different missile configurations, bodies of revolution, non circular shapes, lifting surfaces,

Low Aspect Ratio characteristics, wing – body – tail interference, prediction of overall characteristics of body dominated configurations and lifting surface dominated configurations,

High angle of attack aerodynamics, Shock wave – boundary layer interactions; aerodynamic heating, intake aerodynamics.

Engine airframe integration, airframe flexibility effects on aerodynamics, Stage separation dynamics.

Configuration design methodology of tactical missiles. Design methodology of multistage vehicles.

Wind tunnel testing

Text/References:

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

AFW 601 Ballistics of Bombs & Projectiles

Basics of Ballistics of any projectile, Difference between precision, accuracy and CEP. Internal Ballistics (Guns): Burning of propellants, Vielle's mode and rate of burnings, form function, Resalls' Energy Equation. Internal ballistic solutions, effect of vibrations in loading conditions, Similarity relations. External Ballistics (Guns): Aerodynamic force system. Normal equations. Numerical methods of trajectory computation, Meteorological corrections. Angular motion of the Centre of mass. Drift and deflection, Dispersion of fire. External Ballistics of Rockets: Launch dynamics, plane trajectory, boost plane trajectory models, rocket accuracy (dispersion and stability), rocket-assisted projectiles. 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/References:

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

AFW 602 Design of Air Armament - I

Aerodynamics Decelerators: definitions, types, applications of parachute for escape, recovery and armaments systems. Supersonic inflatable decelerators.

Parachute characteristics: opening characteristics, aerodynamic drag &wake effect, shock load, snatch force, inflation process, reefing, clustering, pressure distribution, deployment methods, critical speeds, parachute stability, stress analysis, trajectory and motion of deployed parachutes, impact attenuators. Parachute malfunctions.
Parachute materials, porosity of fabric. Parachute & reefing system design, Case study on design of parachute recovery and landing system. Testing of Parachutes

Design of aircraft bombs & tail units: Classification, design data, factors affecting bomb design, spatial functioning considerations, bomb design for stability and accuracy requirements. Design and use of cluster bomb.

Design of HE Bomb: Bombs case design, analysis of stresses in thin and thick cylinders, various failure theories, stages of manufacturing of forged bomb case

Design of penetration bomb: description of concrete, crushing strength, setting & hardening. Behavior of concrete on impact of projectile, factors affecting penetration, effect of reinforcement, mathematical calculation of residual velocity, time of penetration and resistive pressure**.** Analysis of stresses in bomb case during normal impact on concrete. Calculation of penetration & depth resistive pressure in rock & soil.

Fuses : Classification, general design considerations, principles of fuse initiation, design, working and safety features of mechanical fuses, safety & arming devices. Introduction to electrical, electronic fuses, proximity and long delay fuses. Latest trends in fuse development

Guided Bombs: Classification and types, Design Criteria, Working principle, Type of Lasing equipment (LDP, PLDs, UAV assisted). Range Enhancement techniques.

Chaffs, flares, EAX and power cartridges: Basic principles, design aspect and lifting methodology.

Text/References:

1. Text Book of Air Armament, Royal Air Force publication.
2. Irwin, Recovery System design Guide, 2006.
3. Air Force Wing Précis on Stores Separation.
4. Knacke TW, Parachute Recovery System Design Manual, 2008.
5. Performance & Design criteria for Deployable Aerodynamic Decelerators (*N*TIS).
6. Air Force Wing Précis on Bomb and Fuse Design.

AFW 603 Airborne Weapon System Effectiveness

Basic tools and methods used in Weaponeering: Weaponeering process, elementary statistical methods, weapon trajectory, delivery accuracy of guided & unguided armaments, target vulnerability assessment, introductory and advanced methods.

Weaponeering process of air launched weapons against ground targets: single weapon directed against point & area target, Stick deliveries, projectiles, cluster munitions, Weaponeering for specific target (bridges, building, tunnels etc), simple collateral damage modeling, and direct & indirect fire system.

Introduction to Fire Control System: definitions, classification, applications of modern FCS.

Text/References:

1. Feller W, An Introduction to Probability Theory and Its Applications, Vol. I & II, 3rd Edition, John Wiley, 2000.
2. Driels M, Weaponeering, AIAA Education series, 2004.

AFW 604 Warhead Design & Mechanics

Introduction to warhead: Configuration and classification. Formation of kill mechanisms and target interaction. Omni-directional, directional and directed energy warheads. Explosives used in warheads.

Blast warheads: Explosion dynamics. Specifications of blast wave. Propagation of blast wave in air. Evaluation and parametric study of blast. Empirical relations and scaling laws. Peak over pressure, Impulse and Damage Number concept. Damaging aspect and target damage criteria of blast warhead. Thermo Baric weapons.

Fragmentation Warheads: Principles, classifications and design considerations. Natural, preformed and controlled fragmentation. Fragment initial velocity and direction of projection calculation. Fragment mass distribution and computation. Aerodynamic effects on fragment motion. Warhead shape design and geometric modeling of fragmentation warhead. Focused mass fragmentation. Kinetic energy rod warheads. Fragment and target interaction mechanics.

Shaped charge warheads: Configuration and classifications. Hollow charge, Flat cone charge and projectile charge warheads. Liner collapse and jet formation mechanism. Jet and slug characterization: Birkhoff theory, PER theory. Jet and slug velocity, mass distribution. Jet radius. Jet break up. Target interaction and jet penetration dynamics. Hydrodynamic theory and rod penetration model. Stretching jet penetration theory. Parameters affecting performance of shaped charge warheads. Wave shapers. Mechanisms to defeat shaped charges.

Introduction to Warhead Simulation techniques.

Text/References:

1. Joseph Carleone, Tactical Missile Warheads, Vol. 155, Progresses in Astronautics and Aeronautics, 1993.
2. Richard M Lloyd, Conventional Warhead Systems Physics and Engineering Design, Vol. 179, Progresses in Astronautics and Aeronautics, 1998.
3. W. P. Walters and J. A. Zukas, Fundamental of Shaped Charges, Wiley- Inter Science Publication,1989.
4. Richard M Lloyd, Physics of Direct Hit and Near Miss Warhead Technology, Vol. 194, Progresses in Astronautics and Aeronautics, 2001.
5. DIAT Air Wing Précis I – 14.

AFW 605 Air Armament Control & Guidance

Basic design features, Design Criteria, Classification and types of Air Launched Missiles, Specific design requirements.

Missile Controls: Missile control methods: Aerodynamic and thrust vector control, Polar and Cartesian control.

Mathematical modeling: Force and moment equations. Linearization, Transfer function representation of airframe.

Missile servo system: Hydraulic, Pneumatic and Electromechanical.

Missile instruments: Accelerometer, gyroscopes, altimeter, resolvers.

Autopilots Design: Autopilot design based on classical approach: Roll and roll rate stabilization. Lateral autopilots based on various combinations of rate gyro and accelerometer feedbacks. Three loop autopilot.

Introduction to sensors & signal processing

Radar Systems: Fundamentals of Radar, Introduction to Pulse, CW, FM-CW & MTI Radar, Tracking Techniques.

Guidance System: Classification of guidance system, phases of guidance, command guidance, MMW seeker head, image infra-red, scene correlation area navigation system and laser based system. Introduction to INS and SDINS.

GPS: Introduction, description of satellite coordinates and calculation of user coordinates. Concept of GPS INS integration.

Missile Kinematics: Trajectory computation, time of flight, Lateral acceleration demand and turning rate for various courses.

Text/References:

1. Merill I. Skolnik, Introduction to Radar Systems, Tata McGraw Hill, 2001.
2. G.M. Siouris, Missile Guidance and Control Systems, Springer Verlag, 2004.
3. G.C. Goodwin, S.F. Graebe, and M.E. Salgado, Control System Design, Prentice-Hall, New Delhi, 2002.

AFW 606 Design of Air Armament – II

Aircraft Guns: Design Criteria, Specific design requirements, Energy requirements in aircraft guns (automatic, blowback, recoil and gas operation), Gatling guns, kinematics diagram. Design of buffers & recuperators, Gun barrels designing and rifling, muzzle breaks & boosters, Current trends in aircraft automatic gun design.

Aircraft Ammunition: Classification and types of ammunition, Design Criteria, Specific design requirements, Gun ammunition propellant and their characteristics, optimization of grain size for a given weapon. Cartridge case design, Ignition system design, Stability of projectile, driving band design, stresses in shells. Terminal considerations and design of ac gun ammunition fuses. Modern trends in ammunition design.

Aircraft Rockets: Design considerations, proof and testing of aircraft rockets.

Text/References:

1. Jacobson SS, Ballistics, CRC Press, 2008.
2. Engineering Design Handbook: Automatic Weapons, AMCP No. 706 – 260, US Army Material Command, Washington, 1990.
3. Brassey's Essential Guide to Military Small Arms: Design Principles and Operating Methods, D Allsop, L Popelinsky et al, 1997.
4. The Machine Gun: Design Analysis of Automatic Firing Mechanisms and Related Components, GM Chinn, Bureau of Ordnance, Department of Navy, US, 1955.
5. Aerodynamics, Propulsion and Structure, E. A. Bonney, M. J. Zucrow, and C. W. Besserer, D.Van Nostrand, New York,1956.
6. Rapid Fire, 2005, William AG, The Crowood Press, UK.

AFW 607 Testing and Certification of Air Armament Stores

Ground Testing: Gun Ammunition, Rockets, Bombs, Fuses, Parachutes, Missiles. Procedure and Instrumentation setup for Testing & Proof of Air Armament stores, Environmental Testing of Air Armament stores, Airworthiness Certification & Failure Investigation Procedure of Air Armament.

Weapon Accuracy Analysis: Concept of probability, probability distribution, systematic and random errors, error in fire dispersion, probability of kill SSKP, CKP, CEP, (SE, PE, MAE,CPE, CD, EPE,SPE).

Carriage & Release: Design criteria for location of weapon station, Effects of external Carriage and Advanced Carriage concepts, calculation of lug & sway brace reactions for single & twin suspension configuration, Bomb carriers. MIL STD 8591, 7743, 1289.

Mathematical Concept of Stores Separation & Towed body: Similarity concept, stores trajectory simulation, modeling of stores separation.

DDPMAS -2002: Definition, Process of development, Development Phase, Production Phase, Indigenization, Flight Testing by user services.

Procurement Policy: Principals of public buying, preparation and approval of ASQRs, Capital & Revenue procurement of stores.

Composite Materials and polymers for AA applications

Materials: Materials for Bomb/ Rocket and Missile Structures. Introduction to Nano materials for military application.

Text/References:

1. DIAT Air Force Wing Précis and MIL STD 8591, 7743, 1289.
2. Joint services guide on Environmental testing of armament stores and missile JSG-0102-1984 and JSS_0256-01.
3. DDPMAS -2002 and Defence Procurement manual -2008.

AFW 608 Fire Control Systems

Introduction to fire control system: Definitions, classification, application of modern FCS, brief description of aircraft and helicopter FCS.

Theoretical aspects of the FCS problems and its solution

Functional elements of FCS : Acquisition and tracking system, fire control computing system, weapon pointing system, command control & communicating element, data transmitting element, integration of functional element into FCS, compatibility problem.

Design Philosophy: Development of mathematical model & simulation, Model verification & validation, filtering and prediction, accuracy consideration and analysis, hit & kill probability theory, error analysis in FCS, fire control testing.

Designing for reliability, maintainability, ease of operation and safety

Text/References:

1. Department Of Defense Handbook, Fire Control Systems—General, Mil-Hdbk-799(Ar), 1996.
2. BS Dhillon, Design Reliability: Fundamental Applications, CRC Press, 2004.

3. Air Force Wing Précis.

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 engg etc, to engineering officers from Indian Navy, Coast Guard, DRDO scientists, DPSUs and GATE qualified students. At the end of the programme the officer/student should be able to undertake R&D work and evaluation of Marine Engineering Equipment systems.

Eligibility: Bachelor's Degree in Mechanical/Marine 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		Total Credits (*)
			L	T/P	
1	ME 607	Computational Fluid Dynamics	3	1	4
2	ME 644	Marine Diesel & Steam Engines	3	1	4
3	ME 645	Marine Gas Turbines	3	1	4
4	ME 646	Nuclear Reactor Engg.	3	1	4
5	--	Elective I	3	1	4
6	--	Elective II	3	1	4
7	PGC-602	Audit 1 and 2	2	0	0
		Total	**20**	**6**	**24**

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 Electives

Sl. No.	Course Code	Course Name
Elective I & II		
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:

1. Bachelor's Degree in Mechanical/Production/Automobile/Mechatronics/Metallurgy and materials/Mining/Aerospace Engineering of a recognized Institute/University.
2. This programme is open for civilian GATE qualified candidates, DRDO Scientists/Officers and Officers from Tri-services. This programme is also open to foreign nationals from the countries approved by GOI.

Organization: M. Tech Mechanical Engineering with 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	AM607	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 631	Product Design and Development	3	1	4
2	ME 630	Design of Machinery	3	1	4
3	ME 608	Finite Element Methods	3	1	4
4	ME 627	Fatigue, Fracture and Failure Analysis	3	1	4
5	--	Elective I	3	1	4
6	--	Elective II	3	1	4
7	PGC-602	Audit 1 and 2	2	0	0
		Total	**20**	**6**	**24**

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 Electives

Sr. No.	Course Code	Course Title
1	ME 607	Computational Fluid Dynamics
2	ME 611	Design for Manufacturability
3	ME 617	Kinematics and Dynamics of Machinery
4	ME 619	Tribology for Design
5	ME 628	Design of Hydraulic and Pneumatic Systems
6	ME 629	Design of Experiments
7	ME 632	Design Optimization
8	ME 633	Mechanical behavior of materials
9	ME 634	Experimental Stress Analysis
10	ME 635	CAD

11	ME 636	MEMS: Design, Fabrication and Characterization
12	ME 637	Design of Pressure Vessels
13	ME 654	Convective Heat & Mass Transfer
14	ME 658	Additive Manufacturing
15	ME 659	Rapid Prototyping
16	ME 660	Heat Exchanger Design
17	ME 662	CAM
18		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:

3. The eligibility for the postgraduate programme will be Bachelor's degree in **Mechanical/ Production/ Automobile/ Materials/ Metallurgy/ Mechatronics** Engineering disciplines from recognized university.

4. 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 L	Credits T/P	Total Credits (*)
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 L	Credits T/P	Total Credits (*)
1	ME 610	Armament & Combat Vehicles-II	3	1	4
2	ME 613	Armour Protection Systems	3	1	4
3	ME 660	Heat Exchanger Design	3	1	4
4	ME 661	Computational Fluid-Structure Interaction and its Applications	3	1	4
5	--	Elective I	3	1	4
6	--	Elective II	3	1	4
7	PGC-602	Audit 1 and 2	2	0	0
		Total	**20**	**6**	**24**

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	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 Electives

S. No.	Course Code	Course Name
Elective I and II		
1.	ME 607	Computational Fluid Dynamics (CFD)
2.	ME 608	Finite Element Methods (FEM)
3.	ME 611	Design for Manufacturability
4.	ME 612	Modeling and Simulation of Military vehicles
5.	ME 654	Convective Heat and Mass Transfer
6.	ME 614	Unmanned Ground Vehicles
7.	ME 615	Trials & Evaluation of Weapon Systems
8.	ME 616	Thermal Management of Defence Equipment
9.	ME 617	Kinematics and Dynamics of Machinery
10.	ME 618	Composite Structures
11.	ME 619	Tribology for Design
12.	ME 620	High Energy Material Technology
13.	ME 621	Dynamics & Armament Mechanisms
14.	ME 622	Ballistics of bombs and projectiles
15.	ME 623	Design of ordnance, basic structure and super structure
16.	ME 624	Small arms and cannons
17.	ME 625	Combat Vehicle Technology
18.	ME 626	Vehicle Dynamics
19.	ME 627	Fatigue, Fracture and Failure Analysis
20.	ME 628	Design of Hydraulic and Pneumatic Systems
21.	ME 629	Design of Experiments
22.	ME 630	Design of Machinery
23.	ME 642	Automatic Control System
24.		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 Name- ***Armament and Combat Vehicles- I***
Course Code- ***ME 601***
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.

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.

Text Books/References:

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

Course Name- ***Advanced Mechanics of Materials***
Course Code- ***ME 602***
Course Outcome:
CO1: Understand the fundamental concepts of stress and strain and the relationship between both through the strain-stress equations in order to solve problems for simple tri-dimensional elastic solids.
CO2: Determine Stress/strain invariants, principal strains and their directions.Analyze theories of failure to design components for safe operation.
CO3: Solve problems relating to non-uniform beams and thin-walled open section. Analyze the stresses in rotating discs, thick cylinder and bars subjected to torsion.
CO4: Develop constitutive relationships between stress and strain for linearly elastic solid and apply the concepts of energy methods in solving structural problems.

Unit I: Theory of Elasticity-Introduction, Stress. Differential equations of equilibrium, strain, compatibility conditions, plane problems of elasticity, stress strain relations, stress functions and applications in 2D problems. Pressurized cylinders & rotating disks, Governing equations, Stresses in thick walled cylinder under internal and external pressures. Introduction to experimental stress analysis.
Unit II: Energy Methods-Work done by forces and strain energy, reciprocal relations, Castigliano's theorems, Fictitious load method, statically indeterminate structures, theorem of virtual work, generalization of Castigliano's theorem.
Unit III: Asymmetrical Bending of beams-Bending of prismatic bars and unsymmetrical bending. Concept of shear centre in symmetric and un-symmetric bending, Plate bending, bending of curved beams.
Unit IV: Torsion of non-circular sections-Introduction, torsion of general prismatic solid section like circular, elliptical, rectangular, triangular shafts, membrane analogy, torsion of thin walled tubes, torsion of thin walled multiple cell closed sections.

Text Books/References:

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

Course Name- ***Fluid Flow & Heat Transfer***

Course Code- ***ME 603***
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.

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.

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 Name- ***Advanced Materials and Processing***
Course Code- ***ME 604***
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.

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.

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, 4^{th} Edition, Pearson Education.
7. M. P. Grover: Fundamentals of Modern Manufacturing: Materials, Processes & Systems , Prentice Hall.

Course Name- **Introduction to Combat Systems**
Course Code- **ME 605**
Course Outcome:

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 system and Combat Vehicle Evaluation Techniques with different types of trials required for futuristic combat vehicle design and finding solution to the existing problems in current inventory of combat vehicles.

Unit I: Threat Spectrum - Types of Conflicts - Low level, Medium level, Heavy conflicts - Combat Vehicle during World Wars I & II - Post world wars Combat Vehicles. Conventional threats - Tank threat, Mine threat, Missile threat; Non-conventional threats - Ariel threat - Aircrafts, Helicopters, Drones - Precision munitions delivered from various platforms - Nuclear threat - Conflicts in builtup areas - Close combat - peace keeping missions.
Unit II: Battle Field Environment - Firepower - Non lethal, low calibre, Heavy calibre (tank / Arty), Cannon launched Missiles; Mobility - Tactical, Strategic, Battle field Mobility - weight, transportability, logistics; Protection - Small arms, Splinters, KE attack, CE Attack, Passive and Active, camouflage and stealth; Command-Control-Communication-Computer-Intelligence (C4I) - Network Centric Warfare - Battlefield Management System - Situational awareness through sensors.
Unit III: Vehicle Configuration - On Road and Off Road vehicles; Soft skinned - logistics, strategic transport (special railway wagons and multi-axle road trailers), Medium Armoured (both wheeled and Tracked) - Infantry Combat Vehicles (ICV), Missile / Mortar Carrier Vehicle, Artillery Vehicles, Armoured Repair and Recovery Vehicle (ARRV), Bridge Layer, Main Battle Tank (MBT).
Unit IV: Man Machine Interface - Human System Integration - Ergonomics - Environmental Control System - Packaging of systems.
Unit V: Maintainability - Design for maintenance - Maintenance Repair and Overhaul (MRO) - Modularity in design - Adaptability to different missions, Line Replaceable Units.
Unit VI: Combat Vehicle Evaluation Techniques - Automotive trials - Specialized test track for automotive trials; Weapon Trials - Special equipment for proving weapon, proving Ammunition and Proving Combat system as a whole; Different types of Trials - Development trials, User trials, Usage trials, Deployment trials.

Text Books/References:

1) Fighting vehicle, TW Terry, Brassey’s, 1991
2) The Greenhill Armoured Fighting Vehicles Data Book - Ian Hogg – Greenhill books - ISBN: 1853673919, 978-1853673917
3) The Encyclopedias of Tanks and Armored Fighting Vehicles – Chris Foss, Will Fowler – Thunder Bay Press (CA) – ISBN: 1571458069, 978-1571458063

4) Tanks inside Out – Michael E. Haskew – ISBN: 1607101106, 978-1607101109 Modern Tanks & Armoured Fighting Vehicles by Simon Dunstan – The Crowood Press, 2005 ISBN:1840371900, 9781840371901.

Course Name- ***Computational Fluid Dynamics (CFD)***
Course Code- ***ME 607***
Course Outcome:
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

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

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

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

Course Name- ***Finite Element Methods***
Course Code- ***ME 608***

Course Outcome:

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.

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

Unit II: 1-D structural problems-*Analysis of axial bar element* - stiffness matrix, load vector, temperature effects, Quadratic shape function. ***Analysis of Trusses-*** Plane Truss elements, Transformation matrix, stiffness matrix, load vector Analysis of Beams - Hermite shape functions – beam stiffness matrix - Load vector - Problems

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

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

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

Practice:

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

Text Books/References:

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

Course Name- ***Mechanical Vibrations***
Course Code- ***ME 609***
Course 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.

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.

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

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

Course Name- ***Armament and Combat Vehicles II***
Course Code- ***ME 610***

Course Outcome:

CO1: Understand the basics of Armament Systems and ballistics, learn fundamentals of Weapon System and its classification, Principles and Factors affecting Design of Weapon, Weapon mount, Projectile and Turret, Ammunition & Missile Feed Systems, Extraction and Ejection Systems. Learn fundamentals of Gun and Rocket; Internal, Intermediate, External and Terminal ballistics and 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.

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

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

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

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

Unit V: Introduction to Weapon Sighting system

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

Unit VI: Introduction to Fire Control System

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

Text Books/References:

1. "Handbook of Infantry Weapons", Part – 1, RMCS, UK, 1987

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

Course Name- ***Design for Manufacturability***
Course Code- ***ME 611***
Course Outcome:
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.

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.

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. Yotaro Hatamura, The Practice of Machine Design, Claredon Press Oxfor, 1999.
6. Ertas Atilia 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 Name- ***Modeling and Simulation of Military Vehicles***

Course Code- ***ME 612***

1. **Introduction to Multi Body Dynamics.**
2. **Vehicle dynamics evaluation using commercial software**

(i) LMS Virtual Lab (or)
(ii) ADAMS, ADAMS (ATV) (or)
(iii) Recurdyn

2(a). Modelling of Track

- Super Element Track Modelling
- Discrete track modelling

2(b). Modelling of tyre
2(c). Modelling of Terrain

- 3D Surface modelling
- Representation of soft terrains

2(d) Steering and motion controls
2(e) Co-simulation techniques
2(f) Modelling of contact elements

- Contact between track and terrain
- Contact between track and other turning gear elements
- Contact between tyre and terrain

3. **Introduction to Modal Analysis**

- Virtual Experimental Modal Analysis (VEMA) using.

4. **Structural analysis of hull and chassis**

- Flexi body MBD modelling

5. **Prediction of vehicle performance characteristics using vehicle dynamics model –**

- Ride evaluation
- Low speed, high speed handling
- Obstacle crossing
- Mobility evaluation

6. **Introduction to CFD softwares.**

- CFD analysis of hull/body for hydrodynamic performance of vehicles engaged in swimming, planning, steering and other manoeuvres.

7. **Armour / Ballistics**

- Introduction to softwares such as LS Dyna, Radios
- Prediction for survivability of blast load or incoming projectile; penetration, or elastic and plastic deformation.

8. **Experimental testing of vehicle and systems for validation of simulation models.**

Text Books/References:

1. Multibody Dynamics: Computational Methods & 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 Name- ***Armour Protection Systems***
Course Code- ***ME 613***
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, electric armour etc. Active protection system layout and integration to platform, Intercepting mechanism and apply the understanding to the design of future systems.
CO4: Understand and evaluate the requirement of different Detection signature management techniques for acoustic, thermal, EM emissions etc. and proposing solution to the existing problems persisting currently.

Unit-I: Type of Threats: Threats to Armoured vehicles and systems. Frontal, top, side and bottom attacks. Armoured distribution on a typist MBT, ICV, body Armour.
Unit II: Structural Design and Protection: Structural requirements of armoured and nonarmoured vehicles; Armour Failure modes against Kinetic Energy (KE); Chemical Energy (CE).
Unit-III: Types of Armour: Small Armour and Splinters; Passive Armour - Rolled Homogenous Armour Steels, Aluminium Armour, Ceramic / Composite armour, Laminated / Spaced Armour, Explosive Reactive Armour; Active Armour - Soft Kill techniques 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), Electric Armour. Methods to detect ERA case studies. Active protection system, Layout and integration to platform, Sensors and control mechanism, Intercepting mechanism and case studies.
Unit-VI: Detection signature management: Signature Management for acoustic, Thermal, usual and EM emissions. Deceptions and decoys, Early warning systems, Camouflages and concealments.

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

Course Name- *Unmanned Ground vehicles*

Course Code- ***ME 614***

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

Text Books/References:

1. Autonomous Mobile Robots by Roland Siegwart, Illah R. Nour bakhsh, Davide Scaramuzza (Printice Hall)
2. Autonomous robots: From biological inspiration to implementation and control, By Bekey, G.A.
3. Intelligent unmanned ground vehicles- autonomous navigation research at carnegie mellon,By Hebert, M.H. Thorpe, C Stentz, A.
4. Robot technology fundamentals, by Keramas, J.G.
5. Principles of robot motion Theory algorithms and implementations by Choset, H. Lynch, K.M. Hutchinson, S. Kantor, G. Burgard, W. Kavraki, L.E. Thrun, S.

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

Course Code- ***ME 615***

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

Unit II: Static test procedures, Shock and vibration tests, 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, Ramin Esfandairi 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 Name- ***Thermal Management of Defence Equipment***

Course Code- ***ME 616***

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

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

Unit I: Heat-transfer fundamentals: conduction, convection, radiation, phase change, and heat transfer across solid interfaces.
Unit II: Heat-generating electronic equipment: ICs, power converters, circuit cards and electrical connectors.
Unit III: Thermal management equipment: heat sinks, interface materials, heat spreaders including liquid loops, and air movers. System design: system packaging architectures, facilities, system analysis. Advanced Topics: spray cooling, refrigeration
Unit IV: Introduction, Basic aspect of compactness, Scaling laws of heat exchangers, surface optimization, Industrial compact heat exchangers: Plate Fin heat exchangers, Tube Fin heat exchangers, Printed Circuit heat exchangers, Plate and Frame heat exchangers, Spiral heat exchangers, Plate and Shell heat exchangers. Surface comparisons, Size, shape and weight relationships, Surface types and correlations, Thermal Design-LMTD method.

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

Course Name- ***Kinematics and Dynamics of Machinery***
Course Code- ***ME 617***

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 Name- ***Composite Structures***

Course Code- ***ME 618***

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

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 For Chracteristion 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 Name- ***Tribology for Design***
Course Code- ***ME 619***
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

Unit I: Introduction-Defining Tribology, Tribology in Design - Mechanical design of oil seals and gasket - Tribological design of oil seals and gasket, Tribology in Industry (Maintenance), Defining Lubrication, Basic Modes of Lubrication, Properties of Lubricants, Lubricant Additives, Defining Bearing, Terminology - Sliding contact bearings -Rolling contact bearings, Comparison between Sliding and Rolling Contact Bearings

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

Unit III: Lubrication of Bearings-Mechanics of Fluid Flow - Theory of hydrodynamic lubrication - Mechanism of pressure development in oil film, Two Dimensional Reynolds's Equation and its Limitations, Idealized Bearings, Infinitely Long Plane Fixed Sliders, Infinitely Long Plane Pivoted Sliders, Infinitely Long Journal Bearings, Infinitely Short Journal Bearings, Designing Journal Bearing- Sommerfeld number – Raimondi and Boyd method - Petroff's Solution - Parameters of bearing design - Unit pressure - Temperature rise - Length to diameter ratio - Radial clearance - Minimum oil-film thickness.
Unit IV: Hydrodynamic Thrust Bearing-Introduction - Flat plate thrust bearing - Tilting pad thrust bearing, Pressure Equation - Flat plate thrust bearing - Tilting pad thrust bearing, Load - Flat plate thrust bearing - Tilting pad thrust bearing, Center of Pressure - Flat plate thrust bearing - Tilting pad thrust bearing, Friction - Flat plate thrust bearing - Tilting pad thrust bearing
Unit V: Hydrostatic and Squeeze Film Lubrication-Hydrostatic Lubrication - Basic concept - Advantages and limitations - Viscous flow through rectangular slot – Load carrying capacity and flow requirement - Energy losses - Optimum design, Squeeze Film Lubrication - Basic concept - Squeeze action between circular and rectangular plates - Squeeze action under variable and alternating loads, Application to journal bearings, Piston Pin Lubrications.
Unit VI: Elasto-Hydrodynamic Lubrication-Principles and Applications, Pressure viscosity term in Reynolds's equation, Hertz's Theory, Ertel-Grubin equation, Lubrication of spheres, Gear teeth bearings, Rolling element bearings.
Unit VII: Gas (Air) Lubricated Bearings-Introduction, Merits, Demerits and Applications, Tilting pad bearings, Magnetic recording, discs with flying head, Hydrostatic bearings with air lubrication, Hydrodynamic bearings with air lubrication, Thrust bearings with air lubrication.
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.

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 Name- ***High Energy Material Technology***
Course Code- ***ME 620***

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 Name- ***Dynamics & Armament Mechanisms***
Course Code- ***ME 621***

Unit I: Equation of motions, Frame of reference. Newtonia, Enterian, Langrangian, Hamiltonium formulation for motion dynamics. Euler angles and transformations. Translatory and Rotary motions. Constraint and unconstraint motion.
Unit II: Mechanisms: Linear, Rotary, Hydraulic and Pneumatic systems.
System dynamics for first and second order systems and response in time and frequency domain.
Unit III: Mechanisms of large Calibre Weapons: Balancing gear, Breech and Firing Mechanisms, Recoil Mechanisms, Laying Mechanisms, Ramming Mechanisms.
Unit IV: Small Arms Mechanisms: Introduction, Operating Mechanisms (Blow back, recoil and Gas operated), Feeding Mechanisms, Trigger and Firing Mechanisms, Ejection and Extraction Mechanisms.
Unit V: Fuze Mechanisms: Safety and Arming Mechanism, Spring Mass Mechanisms, Rotary Mechanisms, Clock work Mechanisms.
Launcher Platform Leveling, Laying, Sighting, Rocket Pinaka, Control Mechanisms.

Course Name- ***Ballistics of Bombs & Projectiles***
Course Code- ***ME 622***

Unit I: Basics of Ballistics of any projectile, Difference between precision, accuracy and CEP.
Unit II: Internal Ballistics (Guns): Burning of propellants, Vielle's mode and rate of burnings, form function, Resalls' Energy Equation. Internal ballistic solutions, Hunt hind Heydenreigh system. Lodue Method. Effect of vibrations in loading conditions, Similarity relations.
Unit III: External Ballistics (Guns): Aerodynamic force system. Normal equations. Siacci form of solutions, Numerical methods of trajectory computation, Meteorological corrections. Angular motion of the Centre of mass. Drift and deflection, Dispersion of fire.
Unit IV: External Ballistics of Rockets: Launch dynamics, plane trajectory, boost plane trajectory models, rocket accuracy (dispersion and stability), rocket-assisted projectiles.
Unit V: Bomb Ballistics: Aerodynamic forces and moments acting on a bomb, Drag co-efficient, Terminal velocity and Ballistic index, Trajectory of bombs, Simulated stores (similitude) and their trajectories, Bomb stability derivatives and analysis (in roll, pitch and yaw), wind tunnel testing, Bomb trajectory calculations

with point mass and Six Degrees of Freedom Equations. Calculation of Moment of Inertia and Centre of Gravity of bombs.

Text Books/References:

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

Robert L McCoy Modern Exterior Ballistics, 2001, , Schiffer Publishing.

Course Name- ***Design of Ordnance, Basic and Super Structure***
Course Code- ***ME 623***

Unit I: Gun Barrel and Tube Launcher: Theory of failure, Gun Barrel Design, Material and Manufacturing by VAR, ESR, etc. Proof of ordnance, Design of Combustion Chambers. Gun tube acoustics.
Unit II: Breech Mechanism: Principles of operation and design of Muzzle Brakes, Fume Extractors and Firing Mechanisms
Unit III: Design of Structural Elements: Design of gun superstructure and basic structures. Curvilinear and soft recoil systems, articulation and suspension systems.

Text Books/References:

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

Course Name- ***Small Arms and Cannons***
Course Code- ***ME 624***

Unit I: Introduction: Classification, Characteristics and Operating Principles. Automatic Fire and Power Source. Principles and Factors affecting the choice and Design of Projectile and Weapon; Heating of Small Arms; Accuracy and Chance of Hit.
Unit II: Operating Principles: Analytical and Comparative Study of Blowback, Recoil and Gas Operation systems, and Externally Driven Weapon Systems.
Unit III: Subsystems: Feed Systems, Trigger and Firing Systems, Extraction and Ejection Systems, Locking and Mechanical Safety and Muzzle Attachments.
Manufacturing; Inspection; Life Estimation; Modern Trends; Typical Weapon Study: INSAS.

Text Books/References:

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

Course Name- ***Combat Vehicle Technology***
Course Code- ***ME 625***

Unit I: AFV Characteristics : Concept of Tank warfare and design philosophies of AFVs, Development of Tanks, Design parameters of combat vehicles to include configuration, overall dimensions etc.
Unit II: Firepower : Characteristics, components, main gun and tank ammunition including ATGMs, secondary armament, Ranging & Sighting systems including NVD, GCE & ALG, Probability of Kill, Errors & Biases, Fire Control system.
Unit III: Mobility : Types, performance parameters, obstacle crossing ability, navigation – GPS & GLNS.
Unit IV: Protection : Types, Armour Protection, Active protection systems, Protection against NBC and Fire.
Tank communication & IFF, Maintainability, Availability, Reliability and Ergonomics.
Unit V: Critical Dimensions and Design : 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 Name- ***Vehicle Dynamics***
Course Code- ***ME 626***

Unit I: Vehicle Ride : Human response to vibration, ISO standards, Response of idealized suspension systems to stop and sinusoidal disturbance in bounce and to wheel out of balance. Combined pitch and bounce motion, application to multi wheel station vehicles. Random ground input excitation, Use of sinusoidal transmissibility function to predict mean square motion of spring mass. Vehicle performance during cornering, Dynamic Vibration Absorber.
Unit II: Wheeled Vehicle : Vehicle transfer function. Kinematic behaviour of vehicles with rigid wheels and with compliant tyres, neutral steer point, static margin, over and under steer. Derivation of generalized equations of motion for a vehicle, stability derivative notation. Solution with two degree of freedom in the steady in yaw. Frequency response in yaw. Extension of two degree of freedom theory to include effects

of traction and braking, self aligning torque, dual wheels and bogies. Development of equations of motion to include roll of sprung mass, Effect on steady state and frequency response.
Unit III: Tracked Vehicle Handling : Analysis of sprocket torques and speeds, required to skid steer a tracked vehicle. Modification of theory to allow for soil conditions and lateral Weight transfer. Application of theory of steering of articulated and half – track vehicles.
Unit IV: 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 Nikolaevich Belousov and Sergey.D.Popov, SAE International, ISBN 978-0768077230

Course Name- ***Fatigue, Fracture and Failure Analysis***
Course Code- ***ME 627***
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.

Unit I: Fatigue of Structures-S.N. curves - Endurance limits - Effect of mean stress, Goodman, Gerber and Soderberg relations and diagrams - Notches and stress concentrations - Neuber's stress concentration factors - Plastic stress concentration factors - Notched S.N. curves.
Unit II: Statistical Aspects of Fatigue Behaviour-Low cycle and high cycle fatigue - Coffin - Manson's relation - Transition life - cyclic strain hardening and softening - Analysis of load histories - Cycle counting techniques -Cumulative damage - Miner's theory - Other theories.
Unit III: Physical Aspects of Fatigue-Phase in fatigue life - Crack initiation - Crack growth - Final

Fracture - Dislocations - fatigue fracture surfaces.
Unit IV: Fracture Mechanics-Strength of cracked bodies - Potential energy and surface energy - Griffith's theory - Irwin - Orwin extension of Griffith's theory to ductile materials - stress analysis of cracked bodies - Effect of thickness on fracture toughness - stress intensity factors for typical geometries.
Unit V: Fatigue Design and Testing-Safe life and Fail-safe design philosophies - Importance of Fracture Mechanics in aerospace structures - Application to composite materials and structures.

Text Books/References:

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

Course Name- ***Design of Hydraulic and Pneumatic Systems***
Course Code- ***ME 628***

Unit I: Hydraulic System & Components-Sources of Hydraulic Power: Pumping theory – Pump classification – Gear pump, Vane Pump, piston pump, construction and working of pumps – pump performance – Variable displacement pumps. Fluid Power Actuators: Linear hydraulic actuators – Types of hydraulic cylinders – Single acting, Double acting special cylinders like tanden, Rodless, Telescopic, Cushioning mechanism, Construction of double acting cylinder, Rotary actuators – Fluid motors, Gear, Vane and Piston motors
Unit II: Design of Hydraulic Circuits-Construction of Control Components : Director control valve – 3/2 way valve – 4/2 way valve – Shuttle valve – check valve – pressure control valve – pressure reducing valve, sequence valve, Flow control valve – Fixed and adjustable, electrical control solenoid valves, Relays, ladder diagram. Accumulators and Intensifiers: Types of accumulators – Accumulators circuits, sizing of accumulators, intensifier – Applications of Intensifier – Intensifier circuit.
Unit III: Pneumatic Systems and Components-Pneumatic Components: Properties of air – Compressors – Filter, Regulator, and Lubricator Unit – Air control valves, Quick exhaust valves, and pneumatic actuators. Fluid Power Circuit Design, Speed control circuits, synchronizing circuit, Penumo hydraulic circuit, Sequential circuit design for simple applications using cascade method.
Unit IV:Design of Pneumatic Circuits-Servo systems – Hydro Mechanical servo systems, Electro hydraulic servo systems and proportional valves. Fluidics – Introduction to fluidic devices, simple circuits, Introduction to Electro Hydraulic Pneumatic logic circuits, ladder diagrams, PLC applications in fluid power control. Fluid power circuits; failure and troubleshooting.
Text Books:
1. Anthony Esposito, Fluid Power with Applications, Pearson Education 2000.
2. Majumdar S.R., Oil Hydraulics, Tata McGraw-Hill, 2000.
3. Johnson, James L., Introduction to Fluid Power, Delmar Publishers, 2003
Reference Books:
4. Majumdar S.R., Pneumatic systems – Principles and maintenance, Tata McGraw Hill, 1995
5. Harry L. Stevart D.B, Practical guide to fluid power, Taraoeala sons and Port Ltd. Broadey, 1976.
6. Michael J, Prinches and Ashby J. G, Power Hydraulics, Prentice Hall, 1989.
7. Dudelyt, A. Pease and John T. Pippenger, Basic Fluid Power, Prentice Hall, 1987.

Course Name- ***Design of Experiments***

Course Code- ***ME 629***

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 Name- ***Design of Machinery***
Course Code- ***ME 630***
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.

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

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 Name- ***Product Design and Development***
Course Code- ***ME 631***
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.

Unit I: Product Design

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

Unit II: Product Development

- Phases of Product Development: Product strategy definition, Product Planning, Product Design, digital & physical testing and validation, Tooling/ Fixture development, Pre-Production, Manufacturing & Sales
- Product strategy definition
- Product Planning
- Competition assessment
- Technical and commercial evaluation of concepts
- Digital & physical testing and validation
- Production readiness and Introduction to Market
- 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”

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 Yotaro Hatamura, The Practice of Machine Design, Claredon Press Oxfor, 1999.
6 Ertas Atilia 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 Name- ***Design Optimization***

Course Code- ***ME 632***

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 Name- ***Mechanical Behavior of Materials***

Course Code- ***ME 633***

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 Name- ***Experimental Stress Analysis***

Course Code- ***ME 634***

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 Name- ***CAD***
Course Code- ***ME 635***
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. Ibrahbim Zeid, "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 Name- ***MEMS - Design, Fabrication, and Characterization***
Course Code- ***ME 636***
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 Name- ***Design of Pressure Vessels***

Course Code- ***ME 637***

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 Name- ***Warship Transmission and Tribology***

Course Code- ***ME 641***

Course Outcome:
CO1: Students will be able to **analyze and apply** basics of power transfer in Marine gear boxes, stresses, noise and modes of failure in gear drives
CO2: Students will be able to **explain** about Navel standards used in design of shafting in marine engines transmission 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

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.

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

Course Name- ***Automatic Control Systems***
Course Code- ***ME 642***
Course Outcome:
CO1: Students will understand basics of control systems like transfer function, closed/open systems, feedback & feed forward systems & draw block diagrams for mechanical, electrical and hydraulic systems
CO2: Students will understand Nyquist criterion, static & dynamic characteristics of transient, steady state, 1st/2nd order control systems using frequency response, stability analysis, root locus analysis.
CO3: Students will understand control system actions & components like discrete/proportional, integral & differential control actions, comparators & actuators, amplifiers, servo motors, control valves
CO4: Students will be able to apply control system basics to pneumatic, hydraulic & electrical systems based on microprocessor, PLC, micro-controller based distributed Marine control systems

Syllabus Details	Outcome

Unit I	CO1
Unit II	CO2
Unit III	CO3
Unit IV & V	CO4

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

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

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

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

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

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

Texts Books:

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 Name- ***Ship Dynamics and Marine Systems***

Course Code- ***ME 643***

Course Outcome:

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

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

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

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

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

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

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

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

Unit IV: NBCD Requirements, Marine Controls and Instrumentation.

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

Texts Books

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

Course Name- ***Marine Diesel & Steam Engines***

Course Code- ***ME 644***

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

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.

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 Name- *Marine Gas Turbines*

Course Code- *ME 645*

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

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.

Texts Books/References

1. Gas Turbine Theory, 5th Ed, Cohen, Rogers & Sarvamuttu, John Wiley & Sons, 2001.
2. Fluid Mechanics and Thermodynamics of Tubomachinery, SL Dixon, 6th Ed, Elsevier, 2010.
3. Gas Turbine 2nd Ed, V Ganeshan, Tata 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 Name- Nuclear Reactor Engineering
Course Code- ME 646
Course Outcome:
CO1: Students will **understand &** be able to **apply** basic knowledge of nuclear physics
CO2: Students will be able to demonstrate **understanding** on safety aspects related to functioning of a nuclear reactor
CO3: Students will be able to **analyse, apply and explain** thermal and hydraulic design aspects of nuclear reactor systems
CO4: Students will **understand &** be able to **explain** basics of control and instrumentation of an nuclear reactor

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

Unit I: Nuclear Reactor Physics: Introduction to nuclear physics: nuclear fission, nuclear reactions and radiations. Reactor analysis, reactor kinetics and control,
Unit II: Nuclear Reactor Engineering: Thermal & hydraulic aspects of reactor design, energy removal. Core and Fuel design. Reactor process system, reactor fuel design. Design aspects of major reactor components, material selection, shielding design. Overview of nuclear fuel cycle. Different reactor systems,
Unit III: Nuclear Reactor Safety: Overview of nuclear safety philosophy, defense in depth principle, different safety systems,
Unit IV: Health Safety: Effects of different types of radiation, dosage, radiation monitoring.
Unit V: Nuclear Reactor Control & Instrumentation: General features of reactor control, control in reactor operation. Basics of reactor instrumentation, instrumentation range and wide range of detectors used. Visit to BARC Mumbai for one day.

Texts Books
1. Nuclear Reactor Engineering: Reactor Design Basics, Volume – 1, Samuel Glasstone and Alexander Sesonske, CBS Publishers and Distributors, 2002.
2. Nuclear Reactor Engineering: Reactor systems engineering, Volume - 2, Samuel Glasstone and Alexander Sesonske, CBS Publishers and Distributors, 2002.
3. Introduction to Nuclear Engineering, John R. Lamarsh and Anthony J. Baratta. Prentice Hall; 3rd editions, 2001.

Course Name- ***Convective Heat & Mass Transfer***
Course Code- ***ME 654***
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

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

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 (4^{th} 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 Sedat Tardu (Wiley)

Course Name- ***Performance Testing and Instrumentation***

Course Code- ***ME 655***

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 Name- ***Marine Hydrodynamics***

Course Code- ***ME 657***

Course Outcome:

CO1: Understand and review of Ideal and viscous incompressible fluid; Kinematics of fluid; Lagrangian and Eulerian methods of description, velocity, acceleration, streamlines, pathlines, vorticity

CO2: Understand the basic Two dimensional motion - velocity potential, stream function, Sources, sinks, dipoles; Flow past a circular cylinder with and without circulation; 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

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.

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; 3^{RD} edition.
2. Milne-Thomson, L. M. (1996) Theoretical Hydrodynamics, Dover Publications, Inc. New York. Introduction to Fluid Mechanics
3. Dean, R. G. & Dalrymple, R. A. (2001) "Water Wave Mechanics for Engineers and Scientists" Allied Publishers Limited, New Delhi (Reprint of World Scientific, Singapore).

Course Name- ***Additive Manufacturing***
Course Code- ***ME658***

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 Name- ***Rapid Prototyping***
Course Code- ***ME 659***

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 Name: ***Heat Exchanger Design***
Course Code: ***ME660***
Course Outcome:

CO1: Understand the basics of Heat exchangers, its classification of different applications. Introduction to Thermal and hydraulic aspects, pressure drop and heat transfer, sizing and rating, LMTD and NTU method etc.

CO2: Understand role of Biot number and its significance in Fin design, lumped parameter analysis, effectiveness, efficiency and thermal resistance of fins. Understand different types of heat exchangers. Evaluate Fouling and corrosion and its effect on heat transfer and pressure drop and calculations for shell and tube heat exchanger.

CO3: Analyze the different components and their functions in connection Heat Pipe and Phase change heat exchangers and apply the understanding to the design of future systems.

CO4: Understand and evaluate the requirement of Heat Exchanger packaging and testing and proposing solution to the existing problems persisting in current inventory of combat vehicles.

Unit I: Introduction to Heat Exchangers: Introduction, Application of Heat exchangers, Classification of heat exchangers, Types of heat exchangers, common terminologies, Introduction to Thermal and hydraulic aspects, pressure drop and heat transfer, sizing and rating, LMTD and NTU method

Unit II: Fin Design: Biot number and its significance, Applicability of Lumped parameter analysis, Fins and its design, Effectiveness and efficiency, Heat transfer from fin array, Thermal resistance concept

Unit III: Heat Exchanger Design: Shell and Tube Heat Exchangers, Fin tube heat exchanger, Plate Fin Heat Exchangers (PFHE), Direct contact heat exchangers, Regenerators and Recuperator, types of regenerators, construction, application, Theory of Regenerator

Unit IV: Fouling and corrosion: Effect of fouling on heat transfer and pressure drop, Fouling mechanisms, single phase liquid side, single phase gas side, Prevention of fouling, Types of corrosion, corrosion control, advantages and disadvantages of water as a medium in heat exchangers

Unit V: Advanced topics: Heat Pipe and Phase change heat exchanger: Heat pipes, construction, working principle, application, and analysis. Special heat pipes, Phase change heat transfer, Phase change heat-exchangers (Evaporators and Condensers)

Unit VI: Heat Exchanger packaging and testing: Heat Exchanger packaging, Air elimination unit, Air blower/ fan power requirements, Safety valves, Heat Exchanger testing: Steady state and dynamic methods

Text Books:

1. Fundamentals of Heat Exchanger Design by Ramesh K. Shah & Dusan P. Sekulic (John Wiley & Sons)
2. Heat Exchangers: Selection, Rating, and Thermal Design by Sadik Kakaç, Hongtan Liu, Anchasa Pramuanjaroenkij (CRC Press)
3. Heat Exchanger Design by Arthur P. Fraas, Fraas (Wiley)

Reference Books:

1. Heat Exchanger design handbook by T. Kuppan
2. Compact Heat Exchangers by William M. Kays andA.L. London, (Krieger Publishing Company)
3. Fundamentals of heat transfer - Frank P. Incropera, David P. DeWitt

Course Name- ***Computational Fluid-Structure Interaction and its Applications***

Course Code- ***ME 661***

Course Outcome:

CO1: Understand the real-life problems of Fluid-Structure Interactions (FSI) and fundamental of governing equations and boundary conditions. Learn Fundamentals of Computational Fluid Dynamics (CFD) using Finite Volume and Finite Element techniques.

CO2: Understand and evaluate Fluid-structure Coupling and Interface handling: Fluid-structure coupling algorithm-Partitioned coupling schemes, Arbitrary Euler-Lagrange (ALE).

CO3: Analyze the different modules and their functions available in AUTODYN software for simulation of coupled Fluid-Structure Interaction problems.

CO4: Understand and evaluate different real-life problems through simulation using ANSYS AUTODYN software.

Unit I: Introduction: Fluid-Structure Interactions (FSI), Real world examples of FSI, Models of the Flow, Finite Control Volume, Infinitesimal Fluid Element, The Substantial Derivative, Physical meaning of Divergence of the Velocity, Continuity, Momentum and Energy Equations, Equations for Inviscid Flow (the Euler Equations), Comments on governing equations, Physical Boundary Conditions.

Unit II: Fundamentals of Computational Fluid Dynamics (CFD): Basic aspects of Discretization, Introduction of Taylor series, Finite Difference and Finite Volume formulation of steady/transient one-dimensional conduction equation, Consistency, Convergence and Stability, Temporal Discretisation Explicit Schemes Implicit Schemes

Unit-III: Fundamentals of Finite Element Method (FEM): Finite Element Formulation Starting from Governing Differential Equations, Weighted Residual Method, The General Weighted Residual (WR) Statement, Weak (Variational) Form of the Weighted Residual Statement, One-dimensional Finite Element Analysis, One-dimensional Heat Transfer

Unit-IV: Fluid-structure Coupling and Interface handling: Fluid-structure coupling algorithm-Partitioned coupling schemes, Arbitrary Euler-Lagrange (ALE) preliminaries, Kinematics, Fluid equations on a moving domain, Structure equations, Strong vs weak coupling

Unit-V: Introduction to ANSYS AUTODYN: Introduction to Autodyn, Graphical User Interface (GUI), Basic features of Autodyn, 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

<u>Text books/References:</u>

1. **Computational Fluid Dynamics the Basics with Applications, Jr., John D. Anderson, ISBN-13: 9780071132107, McGraw Hill Education**

2. Textbook of Finite Element Analysis, P. Seshu, PHI Learning Pvt. Ltd, ISBN: 9788120323155, 9788120323155

3. Computational Fluid-Structure Interaction: Methods and Applications, Yuri Bazilevs, Kenji Takizawa, Tayfun E. Tezduyar, ISBN: 978-0-470-97877-1

4. Arbitrary Lagrangian Eulerian and Fluid-Structure Interaction-eBook, M'hamed Souli, ISBN-13: 9781118618684, Wiley

5. ANSYS AUTODYN User's Manual, ANSYS Inc.

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

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

Course Name- Research Methodology and IPR
Course Code- PGC 01
Course Outcomes:

CO-1	Understanding the fundamentals of research and its methodology
CO-2	Choose the appropriate research design and develop appropriate research hypothesis for a research project
CO-3	Knowledge of manuscript preparation, patents and Intellectual property
CO-4	Technology transfer and application of IPR in various domains

Unit	Syllabus Details
Unit I:	Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations
Unit II:	Effective literature studies approaches, analysis Plagiarism, Research ethics,
Unit III	Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee
Unit IV	Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.
Unit V	Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications
Unit VI	New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

References Textbooks:

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for
2. science & engineering students'"
3. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
4. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
5. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
6. Mayall, "Industrial Design", McGraw Hill, 1992.
7. Niebel, "Product Design", McGraw Hill, 1974.
8. Asimov, "Introduction to Design", Prentice Hall, 1962.
9. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
10. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Course Name- Audit Course 1 & 2

Course Code- PGC 02

AUDIT 1 and 2: ENGLISH FOR RESEARCH PAPER WRITING

Course objectives:

Students will be able to:
1. Understand that how to improve your writing skills and level of readability
2. Learn about what to write in each section
3. Understand the skills needed when writing a Title
Ensure the good quality of paper at very first-time submission

Syllabus

Units	**CONTENTS**	**Hours**
1	Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness	**4**
2	Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticising, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction	**4**
3	Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check	**4**
4	key skills are needed when writing a Title, key skills are needed when writing an Abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature	**4**
5	skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions	**4**
6	Useful phrases, how to ensure paper is as good as it could possibly be the first- time submission	**4**

Suggested Studies:

1. Goldbort R (2006) Writing for Science, Yale University Press (available on Google Books)
2. Day R (2006) How to Write and Publish a Scientific Paper, Cambridge University Press
3. Highman N (1998), Handbook of Writing for the Mathematical Sciences, SIAM. Highman's book.
4. Adrian Wallwork, English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011

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.	**6**

	True friendship. Happiness Vs suffering, love for truth. Aware of self-destructive habits. Association and Cooperation. Doing best for saving nature	
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:** Preamble Salient Features	**4**
3	**Contours of Constitutional Rights & Duties:** Fundamental Rights Right to Equality Right to Freedom	**4**

	Right against Exploitation Right to Freedom of Religion Cultural and Educational Rights Right to Constitutional Remedies Directive Principles of State Policy Fundamental Duties.	
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 Dissemination and research impact.	**2**

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

School of Robotics established in 2020 with the purpose of encouraging multidisciplinary advanced research on a common platform combining various cutting-edge technologies such as Robotics, Industry 4.0, Artificial intelligence & Machine Learning, etc. With the goal to develop the innovative solution based interdisciplinary research platform to achieve academic and research excellence for next generation. School of robotics seeks to combine excellence in education and research to provide students with a balance of intellectual and practical experiences that enable them to address a variety of Defence needs of India.
Experimental and computational facilities being continuously upgraded in the School to carry out significant curriculum development work in Robotics relevant fields. Apart from the regular courses the School 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 Automation and Robotics has been formulated as per the needs of the Defence sector. The Programmes offers a wide choice of specializations, electives and research areas.

Vision of the School:
"The School endeavours to become Centre of Excellence in interdisciplinary innovation and research in futuristic technologies in Automation and Robotics to strengthen the defence advancements and self reliance of the nation"

Mission of the School:
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 Automation and Robotics technologies 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 Automation and Robotics.
PEO2: Students should be capable to undertake R&D, inspection, testing and evaluation of equipment/systems of Automation and Robotics 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 Industrial Automation and Robotics 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 Industrial Automation and Robotics 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 Automation and Robotics

Brief Description: M.Tech.in Automation and Robotics is an interdisciplinary Masters Programme offered by School of Robotics, which is composed of various branches of Engineering such as Mechanical Engineering, Electrical/Electronics Engineering, Computer science/Information Technology Engineering, and Instrumentation Engineering. Due to increasing impact of smart systems and modernization in human life, the demand for students specialized in multidisciplinary areas such as robotics is growing day by day.

The program is designed for eligible candidates interested in designing, controlling and creating systems of robotics and automation.

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.

2. This programme is open under scholarship category for civilian students of any relevant graduation discipline with qualified GATE exam 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.

Organization: M. Tech in Automation and Robotics is a four-semester master’s programme. There are six compulsory courses in the first semester along with four compulsory and two elective subjects in the second semester. In each semester, three tests 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 as well as 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	3	1	4
2	SR 602	Introduction to Robotics	3	1	4
3	SR603	Sensors, Actuators and Drives	3	1	4
4	SR 604	Programming languages for robots	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	0	2
		Total	**20**	**6**	**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 608	Machine vision & Image Processing for Robots	3	1	4
3	SR 609	Industry 4.0	3	1	4
4	SR 610	Automatic Control system	3	1	4
5		Elective-1	3	1	4
6		Elective-2	3	1	4
7	PGC-602	Audit 1 and 2	2	0	0
		Total	**20**	**6**	**24**

Semester- III

S. No.	Course Code	Course	Credits		Total Credits
			L	T/P	
1	SR 651	M.Tech. Dissertation Phase I	14		14
		Total	**14**		**14**

Semester-IV

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

		Total	**14**	**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 (Elective I and II)
1	SR 611	Advanced control system
2	SR 612	Design aspects of automation
3	SR 613	AI and ML for Robotics
4	SR 614	Swarm robotics
5	SR 615	Introduction to Humanoid Robotics
6	SR 616	Field and service Robots
7	SR 617	Aerial Robotics
8	ME 628	Design of hydraulic and pneumatic systems
9	ME 631	Product design and development
10	ME 634	Flexible manufacturing systems
11	ME 635	Computer Aided Design and Manufacturing
12	--	Open elective from other department

Notes:

1. School 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.

Detailed Contents

Semester-I

Course Name-Industrial Automation

Course Code-SR 601

Unit I: Introduction: Automation overview, Requirement of automation systems, Architecture of Industrial Automation system, Introduction of PLC and supervisory control and data acquisition (SCADA). Introduction to communication protocols- Profibus, Field bus, HART protocols.

Unit II: Material handling and identification technologies -Overview of material handling systems, Types of material handling equipment, Design of the system, Conveyor system, Automated guided vehicle system, Automated storage systems, Interfacing handling and storage with manufacturing, Overview of Automatic Identification Methods.

Unit III: Role of computers in measurement and control, Elements of computer aided measurement and control, man-machine interface, computer aided process control hardware, process related interfaces, Communication and networking, Industrial communication systems, Data transfer techniques, Computer aided process control software, Computer based data acquisition system, Internet of things (IoT) for plant automation.

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

Unit V: Distributed Control System: Overview of DCS, DCS software configuration, DCS communication, DCS Supervisory Computer Tasks, DCS integration with PLC and Computers, Features of DCS, Advantages of DCS.

Unit VI: Overview of Industrial automation using robots: Basic construction and configuration of robot, Pick and place robot, Welding robot, Case studies.

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. Frank D. Petruzella, "Programmable Logic Controllers", 5th Edition, McGraw- Hill, New York, 2016.

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.

Course Name- Introduction to Robotics

Course Code-SR 602

Unit I: Introduction to robotics**,** Evolution of Robot, Laws of Robotics, Need of industrial robot: Material transfer application, Machine loading/unloading application and part handling. Introduction to Robot assembly automation, Part joining and Mechanical part mating.

Unit II : Different definitions of Robot, classification based on the motion capability, classification based on the configuration, Types and components of Robot, Anatomy, Robot Terminology-Links, joints.

Unit III : DOF, Specification of a robot, work volume, work space, work object & MTBF, Robot geometrical configuration (PPP, RPP, RRP, RRR, etc) & Selection of Robots, Control Resolution & Spatial Resolution.

Unit IV: Robot work cell, Kinematic systems, spatial descriptions: Position, orientation and frames, Coordinate frames, Mapping between frames (D-H method), translations, rotations and transformations matrices and Homogeneous Transformation Matrix serial and parallel manipulators.

Unit V: Inverse Kinematics of Serial and parallel manipulators-geometric method, Analytical method, velocity, velocity propagation, Jacobian, acceleration, Jacobian-force relationship.

Unit VI: 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.

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.

References:-

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.

Course Name- Sensors, Actuators and Drives

Course Code- SR 603

Unit I: Introduction to sensors, classification, transducers - common conversion methods, Principle of operation of sensors, Classification, static characteristics, selection criteria of sensor, signals conditioning, calibration and testing of sensor. Working principle of operation of industrial sensors, displacement sensors, temperature measurement sensors, pressure measurement sensors, Flow measurement sensors.

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

Unit III: Principle of operation of actuators-Hydraulic, Pneumatic, electric, other- fundamental laws, classification, speed torque characteristics of DC motors, induction motors, synchronous motors, Speed control methods and applications.

Unit VI: Servo motors, switched reluctance motors, BLDC motors, stepper motor types, universal motor, torque motor, construction, torque- speed characteristics, applications, merits and demerits.

Unit V: 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.

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.

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.

References:

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- Programming languages for Robots

Course Code-SR 604

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.

Text 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.
3. R. C. Gonzalez, R. E. Woods and S. L. Eddins*, 'Digital Image Processing Using MATLAB',*Gatesmark Publishing , 2020.

References:

1. A.K.Gupta, S K Arora,'*Industrial Automation and Robotics*', University science press,2012

Course Name- Introduction to Mechanisms (Non Mechanical)

Course Code- SR 605

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

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

Unit III 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.

Practice :

1. MSC Adams tutorials
2. Basic mechanics/mechanisms tutorials in Python/Matlab
3. Mechanisms Design in Solid works

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

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 rectifier, 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. Sensors: temperature sensor, force and pressure sensor, magnetic field sensor, optical sensor, microwave sensor, acoustic sensor, and image sensor.

Unit-V: INTRODUCTION TO OTHER ELECTRONIC SYSTEMS

Analog communication system, digital communication system, wireless communication system, embedded system, real time system, VLSI, RF.

Text/References:

1. Robert L Boylestad, Electronic Devices & Circuit Theory, Pearson Education, 11th Edition, 2013.
2. Thomas L. Floyd, Digital Fundamentals, Pearson Education, 11th Edition, 2015.
3. Thomas L. Floyd, Electronic Devices, Pearson Education, 9th Edition, 2012.
4. Jacob Fraden, Handbook of Modern Sensors, Springer, 4th Edition, 2010.

Course Name-Mathematics for Engineer

Course Code-AM 607

Unit-I Elements of Probability and Statistics: Basic concepts of Probability, Discrete Probability Distributions (Binomial, Poisson etc.), Continuous Probability Distributions (Normal, Exponential, etc.,).

Unit-IIComponents 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

Text/References:

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.
7. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
8. Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.
9. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
10. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
11. Differential Equations and Dynamical Systems, Texts in Applied Mathematics, L. Perko, 3rd Ed., Vol. 7, 2006, Springer Verlag, New York.
12. .S. Gupta.. Calculus of Variation, Prentice Hall of India Pvt. Ltd.

Semester II

Course Name- Robot Dynamics and control

Course Code- SR 607

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.

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

References:

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-Machine Vision and Image Processing

Course Code-SR 608

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.

Text/References:

1. Milan Sonka, Vaclav Hlavac, Roger Boyle, *Image Processing, Analysis and Machine Vision", (2/e)*, 1998.
2. Rafael C. Gonzalez, Richard E. Woods, *Digital Image Processing, (2/e),* Pearson education, 2003.
3. Boguslaw Cyganek& J. Paul Siebert*, An Introduction to 3D Computer Vision Techniques and Algorithms*, Wiley, 2009.
4. E.R. Davies, Royal Holloway, *Machine Vision: Theory, Algorithms and Practicalities, (3/e),* University of London, December 2004.
5. R. Jain, R. Kasturi, B. G. Schunck, *Machine Vision*, McGraw-Hill, New York, 1995.
6. P.A. Janaki Raman, Robotics and Image Processing an Introduction, Tata Mc Graw Hill Publishing company Ltd., 1995.

Course name: Industry 4.0

Course code: SR 609

Unit I: Introduction to Industry 4.0, Sensing & actuation, Communication, Networking Industry 4.0 Globalization and Emerging Issues, evolution of industrial revolutions, Introduction to Internet-of-Things (IoT), Industrial-Internet-of-Things (IIoT), Internet-of-Services (IoS) and the Internet-of-Everything (IoE).

Unit II: LEAN Production Systems, Smart and Connected Business Perspective, Smart Factories Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management.

Unit III : Cyber security in Industry 4.0, Basics of Industrial IoT: Industrial Processes, Industrial Sensing & Actuation, Industrial Internet Systems. Industrial IoT Layers: Sensing, Processing, Communication. Communication, Networking. Big Data Analytics and Software Defined Networks. Machine Learning and Data Science.

Unit IV: Cyber Physical Systems (CPS)', Advanced Robotics, Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL).Augmented Reality and Virtual Reality, Artifical Intelligence, Big Data and Advanced Analysis

Unit V: Industrial IoT for Factories and Assembly Line, Food Industry, Healthcare, Power Plants, Inventory Management & Quality Control, Plant Safety and Security (Including AR and VR safety applications), Facility Management, Manufacturing industry, autonomous vehicles, Applications of UAVs in Industries.

Unit VI: Case studies.

Text/References:

1. "Industry 4.0: The Industrial Internet of Things", by Alasdair Gilchrist (Apress)
2. "Industrial Internet of Things: Cyber manufacturing Systems" by Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat (Springer).

Course Name-Automatic control system-

Course Code- SR 610

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.

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.

Text/References:

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

Elective subjects

Course Name: Advanced Control system

Course code: SR 611

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

Text/Reference:

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.
3. Norman S. Nise, Control Systems Engineering, John Wiley & Sons, 2008.

Course Name: Design aspect of Automation

Course code: SR 612

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.

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

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: AI & Machine Learning in Robotics

Course Code: SR613

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, 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.

Unit VI: Reinforcement learning, case studies in the area of robotics.

Text/ Reference 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.
3. An Introduction to Neural Network, J. A. Anderson, MIT Press, 1995.
4. Self-Organizing Maps, T. Kohonen, Springer.
5. Introduction to AI Robotics, Robin R. Murphy, MIT Press, 2000.
6. Artificial intelligence: a modern approach, Stuart Russell and Peter Norvig, 2002.

Course name- Swarm Robotics
Course code-SR 614

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

Text/Reference:

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.
3. Floreano, Dario, and Claudio Mattiussi. Bio-inspired artificial intelligence: theories, methods, and technologies. MIT press, 2008.
4. Decentralized Spatial Computing, M. Duckham, Springer, 2013

Course Name- Introduction to Humanoid Robotics

Course Code- SR 615

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.

Text Books:-

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

References:

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

Course Name- Field and service Robots

Course Code-SR 616

Unit I Introduction to Field and service robots: History of service robotics – Present status and future trends – Need for service robots – applications examples and Specifications of service and field Robots. Non conventional Industrial robots. Classification, applications, sensing and perception, social and ethical implications of robotics

Unit II Autonomous Mobile robots: Kinematics, locomotion, perception, motion planning and control, localization and mapping. Road map path planning, intelligent unmanned vehicles. Wheeled and legged, Legged locomotion and balance, Arm movement, Gaze and auditory orientation control, Facial expression, Hands and manipulation, Sound and speech generation, Motion capture/Learning from demonstration, Human activity recognition using vision, touch, sound, Vision, Tactile Sensing, Models of emotion and motivation. Performance, Interaction, Safety and robustness

Unit III: Field Robots: Collision Avoidance-Robots for agriculture, mining, exploration, underwater, civilian and military applications, nuclear applications, Space applications. Industrial applications like cleaning robots, wall painting robots, wall plastering robots, vehicle equipment and building robots, etc. Load carrying robots. IDE detection and diffusion robots

Unit IV: Underwater robots: Kinematics and dynamics, modeling and simulation, navigation, guidance and control. Marine data collection (Temperature, other environment parameters)

Unit V: Aerial robots: Basics of aerial robots, sensors and actuators, modelling and control of small Unmanned Aerial vehicles, guidance and navigation of small range aerial robots, Autonomous indoor flight control Air defence robots.

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

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.

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 Book:

1. Modern Control Engineering, K. Ogata, fifth edition.

Course Name -Design of Hydraulic and Pneumatic Systems

Course Code-ME628

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.

Unit II: 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 III: 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.

Unit IV: Accumulators and Intensifiers: Types of 89 accumulators – Accumulators circuits, sizing of accumulators, intensifier – Applications of Intensifier – Intensifier circuit.

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

Text Books:

1. Anthony Esposito, Fluid Power with Applications, Pearson Education 2000.
2. Majumdar S.R., Oil Hydraulics, Tata McGraw-Hill, 2000.
3. Johnson, James L., Introduction to Fluid Power, Delmar Publishers, 2003 Reference Books:
4. Majumdar S.R., Pneumatic systems – Principles and maintenance, Tata McGraw Hill, 1995
5. Harry L. Stevart D.B, Practical guide to fluid power, Taraoeala sons and Port Ltd. Broadey, 1976.
6. Michael J, Prinches and Ashby J. G, Power Hydraulics, Prentice Hall, 1989.
7. Dudelyt, A. Pease and John T. Pippenger, Basic Fluid Power, Prentice Hall, 1987.

Course Name- Product Design and Development.

Course Code- ME 631

Unit I: Introduction- Significance of product design, product design and development process, sequential engineering design method, the challenges of product development,

Unit II: Product Planning and Project Selection- Identifying opportunities, evaluate and prioritize projects, allocation of resources Identifying Customer Needs: Interpret raw data in terms of customers need, organize needs in hierarchy and establish the relative importance of needs.

Unit III: Product Specifications- Establish target specifications, setting final specifications, Concept Generation: Activities of concept generation, clarifying problem, search both internally and externally, explore the output.

Unit IV: Industrial Design-Assessing need for industrial design, industrial design process, management, assessing quality of industrial design, Concept Selection:Overview, concept screening and concept scoring, methods of selection.

Unit V: Theory of inventive problem solving (TRIZ)-Fundamentals, methods and techniques,

General Theory of Innovation and TRIZ, Value engineering Applications in Product development and design, Model-based technology for generating innovative ideas

Unit VI: Concept Testing- Elements of testing: qualitative and quantitative methods including survey, measurement of customers' response. Intellectual Property- Elements and outline, patenting procedures, claim procedure, Design for Environment-Impact, regulations from government, ISO system.

Text/Reference books:-

1. Ulrich K. T, and Eppinger S.D, *Product Design and Development*, Tata McGraw-Hill Education, 2003
2. Otto K, and Wood K, *Product Design*, Pearson, 2001.
3. By Semyon D. Savransky, *Engineering of creativity: Introduction to TRIZ methodology of inventive Problem Solving*, CRC Press, Aug 29, 2000.
4. Michael A. Orloff, *Inventive thinking through TRIZ: a practical guide*, Springer Verlag, 2003.
5. John Terninko, AllaZusman, *Systematic innovation: an introduction to TRIZ; (theory of inventive Problem Solving)*, CRC Press., Apr 15, 1998.

Course Name- Flexible Manufacturing Systems

Course Code- ME634

Unit I: Definition of an FMS-need for FMS, types and configuration, types of flexibilities and performance measures. Economic justification of FMS. Development and implementation of FMS-planning phases, integration, system configuration, FMS layouts, simulation

Unit II: Functions, types, analysis of material handling systems, primary and secondary material handling systems-conveyors, Automated Guided Vehicles-working principle, types, traffic control of AGVs. Role of robots in material handling.

Unit III: Automated storage systems- storage system performance - AS/RS-carousel storage system, WIP storage systems, interfacing handling and storage with manufacturing - Planning, scheduling and computer control of FMS, Hierarchy of computer control, supervisory computer.

Unit IV: DNC system- communication between DNC computer and machine control unit, features of DNC systems - System issues, types of software - specification and selection- trends-application of simulation and its software, Manufacturing Data systems- planning FMS data base.

Unit V : Modelling of FMS- analytical, heuristics, queuing, simulation and petrinets modeling techniques - Scheduling of operations on a single machine- two machine flow shop scheduling, two machine job shop scheduling - three machine flow shop scheduling- scheduling 'n' operations on 'n' machines, knowledge based scheduling, scheduling rules, tool management of FMS, material handling system schedule.

Texts /References:

1. N K Jha, *Handbook of Flexible Manufacturing Systems*, Academic Press,2012.
2. Raouf, M. Ben-Daya, *Flexible Manufacturing Systems: Recent Developments*, Elsevier,09-Feb-1995.

Course Name- Computer aided design and manufacturing

Course Code-ME 635

Unit I: Criteria for selection of CAD workstations, Shigle Design Process, Design criteria, Geometric modeling, entities, 2D & 3D Primitives. 2D & 3D Geometric Transformations: Translation, Scaling, Rotation, Reflection and Shearing, concatenation.

Unit II: Graphics standards: GKS IGES, PDES. Wire frame modeling: Curves: Curve representation. Analytic curves – lines, Circles, Ellipse,Conis.Syntheticcurves–Cubic,Bezier,B-Spline,NURBS-Surfaceentities,Surface Representation.

Unit III: Analytic Surface – Plane Surface, Ruled Surface, Surface of Revolution, Tabulated Cyliner. Synthetic Surface-Cubic, Bezier, Bspline, Coons - Graph Based Model, Boolean Models, Instances, Cell Decomposition & Spatial – Occupancy Enumeration, Boundary Representation (B-rep) & Constructive Solid Geometry (CSG)

Unit IV: Feature Based Modeling, Assembling Modeling, Behavioral Modeling, Conceptual Design & Top Down Design.

Unit V: Capabilities of Modeling & Analysis Packages such as solid works, Unigraphics, Ansys, Hypermesh. Computer Aided Design of mechanical parts and Interference Detection by Motion analysis.

Text/Reference:

1. M Groover and E. Zimmers, CAD/CAM: *Computer-Aided Design and Manufacturing*, Pearson Education,1983.
2. A J Medland, *CAD/CAM in Practice*, Springer science and media,2012

Course Code	**PGC-601**
Course Name	**Research Methodology and IPR**
L – T – P - C	**2 – 0- 0 – 2**

Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**PGC/All Departments DIAT**

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

CO1: Understanding the fundamentals of research and its methodology
CO2: Choose the appropriate research design and develop appropriate research hypothesis for a research project
CO3: Knowledge of manuscript preparation, patents and Intellectual property
CO4: Technology transfer and application of IPR in various domains.

Course Contents

Unit I: Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations
Unit II: Effective literature studies approaches, analysis Plagiarism, Research ethics,
Unit III Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and
assessment by a review committee
Unit IV Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.
Unit V Patent Rights: Scope of Patent Rights. Licensing and transfer of technology.
Patent information and databases. Geographical Indications
Unit VI New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Texts / References

Stuart Melville and Wayne Goddard, "Research methodology: an introduction for
science & engineering students'"
Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for
beginners"
Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
Mayall, "Industrial Design", McGraw Hill, 1992.
Niebel, "Product Design", McGraw Hill, 1974.
Asimov, "Introduction to Design", Prentice Hall, 1962.
. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Course Code	**PGC-602**
Course Name	**Audit Course**
L – T – P - C	**2 – 0- 0 – 0**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**PGC/All Departments DIAT**

Unit I: English for Research Paper Writing

Unit II: Disaster Management Unit II: Sanskrit for Technical Knowledge Unit IV: Value Education Unit V: Constitution of India Unit VI: Pedagogy Studies Unit VII: Stress Management by Yoga Unit VIII: Personality Development through Life Enlightenment Skills

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

The Department of Computer Science and Engineering was established in 1987. The Department of Computer Science & Engineering offers M. Tech., M.S (by Research) and Ph.D. programs for DRDO scientists, Tri-services and GATE qualified students. Currently, there are 06 faculty members in the department with PhD Degrees. Currently, the department has 12 PhD research scholars and 36 M.Tech. students.

The thrust areas of the Department are Cyber Security, Ethical Hacking, Information Warfare, Network Centric Warfare, Cryptography, Network Security, Information Security Management Systems, Digital Forensics, Malware Analysis, Multimedia Security, Wireless Security. The faculty are also actively working in the following domains: Computational Intelligence, Machine Learning, Artificial Intelligence, SAR Imaging, Data Mining, Trusted Computing, Secure Software Engineering, Program Analysis, Malware Analysis, High Performance Computing, Soft Computing, Modelling and Simulation, Social Network Analysis etc.

The Department has successfully organized Two Weeks short term training courses on Artificial Intelligence and Machine Learning, Cryptology and Cyber Security for Navy Officers, NTRO (National Technical Research Organization) in May 2022, October 2021 and Oct 2019; NCECE 2016 (National Conference on Electronics and Computer Science – Theme: Defence Applications) Sponsored by BEL and NCSDAQC 2017(National Cyber Security Seminar, Debate and Quiz Contest) during July 2017 sponsored by DRDO.

The Department has also conducted several workshops on Ethical Hacking, Cyber Security, Nine Algorithms, IT and Defence etc. The department had received NVIDIA academic research grant, 2018 for deep learning-based research activities.

The Department of Computer Engineering is associated with the data center activities to facilitate the email, WiFi, internet, web hosting, etc. to the DIAT campus. The establishment of National Knowledge Network facility, Virtual Classroom with Video Conferencing, campus-wide Wi-Fi connectivity, PHMC CCTV facility in DIAT are important initiatives of Computer Science & Engineering Department.

The M. Tech. degree in Computer Science and Engineering had started in the academic year 2009 and the two batches have passed out till June 2012. The Department has started M.Tech. with specialization in Cyber Security since July 2011. The first batch passed out in June 2013.

The Department has very good relations with industry, DRDO labs and other academic institutes, hence has a strong placement record.

Institute Vision

To be a Center of Excellence of international repute for Education, Training and research in Advanced Technologies with a view to strengthen national security and self reliance.

Institute Mission

To evolve as an Innovative Unique Research University to develop indigenous contemporary Defence related technologies in Navigation Systems, Wireless Sensors, Efficient Propulsion Systems, Weapon Systems for DRDO and Defence Services, provide technological solutions to the Services to optimise combat battlefield effectiveness and above all produce qualified quality manpower which can truly become an instrument for building a strong indigenous technology base in the context of creating a performing Defence Industrial Base in India.

Department Vision

To be a center of excellence of international repute to provide high quality education, research and training in the area of Cyber Security (CS) and Artificial Intelligence (AI) to promote innovation and entrepreneurship skills amongst the students with a view to strengthen national security and self-reliance.

Department Mission

M1: To build strong education, teaching and research environment in the field of Cyber Security (CS) and Artificial Intelligence (AI) to meet requirements from defence, specially related to national security.

M2: To strive for continuous learning, innovation, entrepreneurship and quality research culture amongst the student community through effective government, industry & academia collaboration.

M3: To encourage ethics, team work and technological leadership skills amongst students to solve complex engineering problems collaboratively by imparting strong theoretical foundation complemented with extensive practical training.

M4: To develop high quality indigenous technological solutions catering defence and civil needs by carrying out multidisciplinary collaborative research.

Program Educational Objectives (PEOs)

PEO1:
The MTech 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 MTech Computer Science and Engineering with specialization 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 problem. The present programme is conceived to understand, assimilate & use the advancedtechnologies 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 MTech 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 MTech 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 MTech 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.

M.Tech in Cyber Security
Course Structure 2022-2024

Brief Description:

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.

Program Objectives:

The MTech(Cyber Security) programme aims at developing Human Resources in the field of Cyber Security with a thrust on defence related problems. The present programme is conceived to understand, assimilate & use the advanced technologies to design and develop secure systems, comprehend different types of cyber attacks, methods and technologies to develop secure IT infrastructure. Advanced technologies from domains such as Network security, Cryptography, Ethical Hacking, Digital Forensic, Malware Analysis, Information Security Management and Trusted Computing techniques have been selected. After completing this course, students are expected to
understand and practive the essential concepts related to Information Security, Incident Responses, Digital Evidence Analysis, Cyber Attacks, Design and Development of secure systems, Penetration Testing etc.

Pre-requisites/Eligibility: Fulltime BE/B.Tech. in Computer Science/Electronics /Electrical/ Communication/Telecommunication/ Information Technology or Fulltime M.Sc./MCA in Computer Science with valid gate score in CS/ECE.

Program Outcome: To generate highly skilled manpower, not only to research, design, develop and test reliable secure systems but also to install, deploy, utilize & maintain them throughout their life span to support information security throughout the organization.

Organization: The Programme curriculum has been designed considering the cyber security requirements of Industry and Defence research and development. It is designed and reviewed by panel of experts chosen from various DRDO labs and leading academic institutions. Each subject of 4 credits is delivered by subject 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 3rd and 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.

M.Tech. in Computer Science and Engineering (Cyber Security)

SEMESTER I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	CE-694A	Data Security & Privacy	3	1	4
2	CE-665A	Security Audit and Penetration Testing	3	1	4
3	CE-663	Applied Cryptography	3	1	4
4	CE-662A	Advanced System Security	3	1	4
5	CE-684	Digital Forensic	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	CE-664A	Network and Cloud security	3	1	4
2	CE-694	Cyber Physical Systems	3	1	4
3		Elective – I (From CSE)	3	1	4
4		Elective – II (From CSE)	3	1	4
5		Elective – III	3	1	4
6		Elective – IV	3	1	4
7	PGC-602	Audit 1 and 2	-	-	-
		Total	**18**	**6**	**24**

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**

List of Audit Subjects (Applicable for Sem - II):

Sr.No.	Course Code	Course
	PGC-602	English for Research Paper Writing
2.		Disaster Management
3.		Sanskrit for Technical Knowledge
4.		Value Education
5.		Constitution of India
6.		Pedagogy Studies
7.		Stress Management by Yoga
8.		Personality Development through Life Enlightenment Skills

List of Open Electives:

Sr.No.	Course Code	Course
1.	CE 669	Reverse Engineering & Malware Analysis
2.	CE 683	Information Warfare
3.	CE 689	Fault Tolerant Computing Systems
4.	CE 690	Parallel & Distributed Systems
5.	CE 691	Secure Wireless Sensor Networks
6.	CE 667	Trustworthy Computing
7.	CE 692	Computational Geometry & Applications
8.	CE 694	Big data Analysis & Algorithms
9.	CE 695	Cyber-Physical & Self-Organising Systems
10.	CE 69F	Theory of Computation
11.	CE 697	Biometric Security
12.	CE 698	Multimedia Security
13.	CE 699	Internet of Things
14.	CE 604	Computational Intelligence
15.	CE 632	Computer Vision
16.	CE 70A	Formal Specification and Verification of Programs
17.	CE 70B	Advanced Algorithms
18.	CE 700	Quantum Computing
19.	CE 70E	Machine Learning in Python
20.	CE 70G	Blockchain Technology
21.	CE 682	Secure Software Engineering
22.	CE 639	Practical Machine Learning
23.	*AM 625*	*Digital Image Processing*
24.	*AM 628*	*Computational Number Theory and Cryptography*
25.	*EE 612*	*Advanced Wireless Communication*
26.	*EE 613*	*Electronic Warfare*
27.	*EE 618*	*DSP System Design*
28.	*TM 609*	*System Engineering*
29.	*TM 611*	*Software Projects Management*

Subject Code	**CE694A**
Subject Title	**Data Security & Privacy**
Credit	**04**
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** One Final Evaluation at the End of the Term **50 Marks** Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100 Marks
Prerequisite	None. First 10 hours will be devoted for Prerequisite learnings related to basics of Databases (04 hours), Computer Networks (02 Hours), Operating System (02 Hours), Trends in evolutions of Compute-Devices (02 Hours)
About the Course	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 their skills and interests.
Course Outcomes	To educate the stakeholders on the growth of importance of application of AIML and information security. Along with personal utilization of systems, the

<table>
<tr><td></td><td colspan="4">privacy matters in the government, enterprise arenas. The study will significantly broaden the scope of individuals who must be aware of relevant issues as part of their work.
To meet end-user, administrator & system designer perspectives, develop skill sets to be resourceful in building and handling knowledge & information systems. Enhance analytical capabilities to evaluate a domain specific and technical area. Multi-Disciplinary Course useful to any engineering discipline who use computer.</td></tr>
<tr><td>Course Outcomes</td><td colspan="4">Bloom’s Taxonomy:

Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create</td></tr>
<tr><td rowspan="5"></td><td>CO Title</td><td>Level</td><td>Descriptor</td><td>Expected Outcome</td></tr>
<tr><td>CO1: Student will be able to examine and identify Data Models for various applications + A general background in concepts of privacy at National & International Scenarios</td><td>L1, L2</td><td>Remember, Learn</td><td>20%</td></tr>
<tr><td>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;</td><td>L3, L4</td><td>Apply, Analyse</td><td>20%</td></tr>
<tr><td>CO3: Student will be able to analyze & apply multi-dimensional data models for complex scenarios + Knowledge of technologies and regulations concerning information security from both data protection and law enforcement perspectives.</td><td>L4, L5</td><td>Analyse, Evaluate</td><td>20%</td></tr>
<tr><td>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.</td><td>L5, L6</td><td>Evaluate, Create</td><td>40%</td></tr>
<tr><td>Summary of the Course OutCome</td><td colspan="4">At the end of the course, a student will have an understanding of the concepts of data models, inherent security mechanisms using data models and issues necessary to address emerging areas of data security and privacy in their potential or current careers. Broadly defined roles include, but certainly are not limited to, systems managers, developers, and engineers; librarians, records managers and other archivists; business managers whose areas of responsibility include systems; data analysts; public and private sector policy professionals; and privacy and security professionals.</td></tr>
<tr><td colspan="5">Syllabus Description</td></tr>
</table>

Basics & Preliminaries	Types of Data Models, Role of Basic and Advanced Data Structures in Data Models, Basic Dictionary Data Types; Algorithms and basics of analysis, OS & Algorithms in Parallel Environments; Protocols of Computer Networks preliminaries, Concerns for Data Security and Privacy Ref. Cormen et al, Horowitz Sahani, Bipin Desai, Korth et al. Kurose Ross	Grad. Level Text Books, given ref.	10 Hours	CO1, PO1
Unit-1	Security Architectures- Information Systems; Database management Systems; Information Security CIA; Information Security Architecture; Database Security levels' Menances to Databases; Asset Types & their values	Text Book-1, Ch-1 Text Book-2, Ch-1	08 Hours	CO1, PO1
Unit-2	Database Security Methods Environments: Parallel DBs, Distributed DBs, Database security Methodology; Database Security Definition	Text Book-1, Ch-1 Text Book-2, Ch-2,3	04 Hours	CO1, PO1
Unit-3	Profiles, Password Policies, Privileges, and Roles Defining and using Profiles: Creating Profiles in SQL Servers & end users; Password Policies, Privileges, Tables and Database Objects Privileges, Column-Level Privileges; Creating, Assigning and Revoking User Roles	Text Book-1, Ch-4 Text Book--2, Ch-4	06 Hours	CO1, CO2, PO1, PO2
Unit-4	Database Application Security Models: Security Models: Access Matrix Model, Access Modes Models; Application Types: Client/Server Application; Web Application, Data Warehouse, Data Stream Applications	Text Book-1, Ch-5 Text Book-2 Ch-5, 6, 7, 8	06 Hours	CO3, PO2, PO3
Unit-5	Virtual Private Databases: VPD, Implementation, VPD Row Col Security	Text Book-1, Ch 6	06 Hours	CO3, PO2, PO3
Unit-6	Database Auditing Models Technical Audit Environment, Process, Objectives, Classification Types, Incidence Reports, Level of escalations.	Text Book-1 Ch 7, 8, 9	06 Hours	CO4, PO2, PO3

	Inclusion of policies, laws and regulatory aspects, Privacy and Ethics, Data protection modeLS, Computation systems for protecting delimited data- MinGen, Datafly, Mu-Argus, k-Similar; Protecting textual documents: Scrub. Application Data Audit: DML Action Audit; Triggers; Fine-Grained Auditing FGA; Application Errors; PL-SQL Environments, Audit DB Activities	Text Book-2, Ch-12,13		
Unit-7	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, Data and AIML Models. Project Cases data Security and Privacy: Online Databases; CSV files to Structured Environments, SCADA, IoTs,	Text Book-1, Ch-10 Text Book-2 Ch.9,10,1 1	06 Hours	CO1 , CO4 , PO2, PO3
Text Books (MUST Know)	Text Book 1 Hassan A. Afyouni,―Database Security and Auditing‖, Third Edition, CengageLearning,2009. Text Book-2: Ron Ben Natan, Implementing Database Security and Auditing, Elsevier Digital Press, 2005		Must Know.	
Reference Books (SHOULD Know)	Reference Book-1 Charu C. Aggarwal, Philip S Yu ―Privacy Preserving Data Mining ‖: Models and Algorithms, Kluwer Academic Publishers, 2008		Should Know.	
Consortium, e-books and Web Link references (SHOULD/ Could Know)	W3.org Meity.gov.in SIGSAC SIGSEC acm.org Isca-speech.org Issa.org Oracle.com/database/security Thelawreviews.co.uk Data Security Council of India (DSCI) prsindia.org iso.org ISO/IEC 27000/27001/27002		Should & Could Know.	
Laboratory Assignments/ Demonstrations				
LAB Assignment s	*Each student will work on unique case study. Will require approval of the same at the beginning. Report submission is essential for each Lab Assignment.			
1	Describe the Use Case*. Model the case study. Abstract. Apply & implement DDL.	Unit-1,	02 hours	CO1

2	Using the case-study, Apply and implement Security Model. Analyse Threats. Wrt Roles, Access Rights.	Unit-2	02 hours	CO2
3	Apply, analyse and evaluate ACID Properties. Identify Threats and implement a Mitigation-technique to secure the data-tuples.	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 Audit wrt Application/Domain Control	Unit 6	02 hours	CO4
7	Create use case environment, implement & perform audit wrt Technology	Unit 6	02 hours	CO4
8	Create model and implement a security feature to demonstrate data security.	Unit-7	02 hours	CO4
9	Assigned ISO module's Study, Audit and Presentation.	Unit 1 to 7	Sem	CO4
10	Mini-project. Implementation and Demonstration. Report Submission is essential	Unit 1 to 7	Sem	CO4

Subject Code	CE663
Subject Title	**Applied Cryptography**
Credit	**04**
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	03 – monthly test + 01 Final Evaluation 1. Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** 2. One Final Evaluation at the End of the Term **50 Marks** 3. Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100
Prerequisite	Basic understanding of mathematics concept like Prime numbers, Group, Ring and Fields Theory
Objective	Understanding of basic encryption and authentication schemes and issue related to cryptanalysis and be able to determine the strength and weakness of the encryption/authentication schemes.
Course Outcome	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			
Syllabus Details		**Book**	**Hours**	**Outcome**
Unit – I:.	Classical Encryption Techniques and their Cryptanalysis: Symmetric cipher model, Substitution techniques, Transposition techniques, Steganography, One-Time Pad (Vernam's Cipher), Limitations of Perfect Secrecy, Shannon's Theorem	Text Book-1	6	CO3, & CO4
Unit – II:	Private-Key Encryption Schemes and Block Ciphers: Pseudorandom Functions and Permutations, Private-Key Encryption Schemes from Pseudorandom Functions, DES – The Data Encryption Standard, Attacks on DES, Single-Round DES, Two-Round DES, Three-Round DES, Brute Force Search, Best Known Attacks on Full DES, AES, Stream cipher A5	Text Book-1	8	CO1, & CO3
Unit – III :.	Number Theory: Prime numbers and factoring, modular arithmetic, computations in finite fields, Discrete logarithms	Text Book-1	6	CO1, & CO3
Unit – IV:	Public-Key (Asymmetric) Cryptography: Public-Key Problems and Mathematical Background, Diffie-Hellman Key Agreement, El-Gamal Encryption Scheme, RSA Encryption, Security of RSA, Hybrid Encryption , Attacks on RSA, Private and Public-Key Reversal, Common Modulus Attack, Simplified Broadcast Attack,Timing Attacks, Elliptic Curve Cryptography, Homomorphic Encryption.	Text Book-1	6	CO2, & CO3
Unit – V:	Hash Functions: Definition and Properties, Constructions of Collision-Resistant Hash Functions, Random Oracle Model.Hashalgorithms:MD5,SHA-256.Message Authentication, Digital Signatures and Applications, Definitions, Constructions, Certificates and Public- Key Infrastructure, Combining Encryption and Signatures – SignCryption.	Text Book-1	6	CO3, & CO4
Unit – VI:	Secure key distribution using Quantum techniques, Hash based Cryptography	Text Book-3	6	CO3
Textbooks:				
"Cryptography & Network Security" by William Stallings 7th Edition, Pearson Education Asia. Kahate A, "Cryptography & Network Security", Tata McGraw Hill. Post-Quantum Cryptography by Daniel J. Bernstein, Johannes, Buchmann, Erik Dahmen, Springer. ISBN: 978-3-540-88701-0. **References**: "Applied Cryptology" by Schiner Bruce, John Wiley & Sons. "Introduction to Cryptography with Coding Theory" by Wade Trappe & Lawrence C Washington, New Jersey, Pearson Education.				

CharlieKaufman, Radia Perlman and Mike Speciner, “Network Security: Private Communication in a Public World”, Prentice Hall of India Private Limited. Behrouz A. Forouzan, “Cryptography and Network Security”, McGraw Hill Jonathan Katz and Lindell, “Introduction to Modern Cryptography: Principles and Protocols”,Chapman and Hall/CRC				
Lab Assignments				
Lab 1	To encrypt the text containing numbers using Playfair Cipher	Unit-1	02 hours	CO3, & CO4
Lab 2	To encrypt the image containing RGB values in the pixel using playfair	Unit-1	02 hours	CO3, & CO4
Lab 3	Programme to find the multiplicative inverse of an integer	Unit-3	02 hours	CO1, & CO3
Lab 4	Programme to find the polynomial inverse	Unit-3	02 hours	CO1, & CO3
Lab 5	Programme to implement the Key expansion of Data Encryption Standard	Unit-2	02 hours	CO1, & CO3
Lab 6	To encrypt the text file using the using A5 Stream cipher	Unit-2	02 hours	CO1, & CO3
Lab 7	Programme for Fair Coin Toss	Unit-4	02 hours	CO2, & CO3
Lab 8	Develop a system to Securely Info Exchange between 2 Ends (Mini Project)	Unit-2,3,4, 5	02 hours	CO1, & CO3
Lab 9	Develop code for symmetric key encryption.	Unit-2, 6	02 hours	CO1, & CO3
Lab 10	Light weight symmetric key encryption applications.	Unit-2	02 hours	CO1, & CO3

Subject Code	**CE665A**
Subject Title	**Security Standards & Penetration Testing**
Credit	**04**
Type of Subject	-Core (MTech in CSE) -Professional Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** One Final Evaluation at the End of the Term **50 Marks** Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100 Marks
Prerequisite	Basic computer networking, operating systems and computer programming knowledge is required.
Dept	CSE
Course Objectives	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		
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create		
	CO Title	**Level**	**Descriptor**
	CO1: 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)	L1, L2	Remember, Understand
	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)	L3	Remember, Understand Analyse
	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)	L3	Remember, Understand Analyse
	CO1, 03: End semester Exam	L4	Apply, Analyse

Syllabus Description

Basics & Preliminaries	**Details**	**Books & References**	**Duration**	**COs**
Unit-1	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)	Textbooks - 1,2	12L	CO1
Unit-2	Security audits and assurance, Information Security Policy, Standards, and Practices, Asset Management,	Textbooks - 2,3	12L	CO3

	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-3	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	Textbooks - 2,3,4,5,6 References -1-7	12L	CO2
Unit-4	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	Textbooks - 4-6, / References -1-7	12L	CO2
	LAB/ Assignments/Student Presentations [2T/P per week		02L/ Wee k	CO4
Text Books (MUST Know)	Michael E Whitman, Herbert J Mattord, “Principles of Information Security”, Course Technology, 3rd Edition, 2008. Dhavale, S. V. (2019). Constructing an Ethical Hacking Knowledge Base for Threat Awareness and Prevention (pp. 1-305). Hershey, PA: IGI Global. Stuart McClure, Joel Scambray, George Kurtz, “Hacking Exposed:n/w sec secrets and solutions”, Mcgraw Hill, 2012			

Reference Books (SHOULD Know)	Various Security Standards - ISO 27000 series published by ISO. Department of Defense Standard, Department of Defense, “Trusted Computer System Evaluation Criteria”, Orange Book. Dieter Gollmann, “Computer Security”, John Wiley and Sons, Inc., 3rd edition, 2011 David Kennedy, Jim O’Gorman, Devon Kearns, and MatiAharoni, ”Metasploitpentest guide”,No starch Press, san Francisco, 2011 Bastian ballman, “Understanding n/w hacks:attack and defense with python”, Springer,2012 Rich Annings, HimanshuDwivedi, Zane Lackey, ”Hacking Exposed 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 Krutz, R. L. & Vines, R. D., “The CISSP and CAP Prep Guide”, Platinum Edition, New York, Wiley Publishing., 2006. Nina Godbole, “Information Systems Security: Security Management, Metrics, Frameworks and Best Practices”, Wiley India Pvt Ltd, 2012. . William Stallings and Lawrie Brown, “Computer Security: Principles and Practice”, 2nd edition, Pearson, 2012.

Laboratory Assignments/ Demonstrations

1	Study Windows Essential Tools-Part 1	Unit - 1	02 hours	CO1, CO2,CO3, & CO4
2	Study Windows Essential Tools-Part 2	Unit - 1	02 hours	CO1, CO3, & CO4
3	Study Sysinternals utilities to manage, diagnose, troubleshoot, and monitor a Microsoft Windows environment	Unit - 2	02 hours	CO2, CO3, & CO4
4	Study passive information gathering tools.	Unit - 3	02 hours	CO1, CO3, & CO4
5	Write Security Policy Document	Unit - 3	04 hours	CO1, & CO4
6	Case study: LDRA and Parasoft tools	Unit - 3	02 hours	CO2, & CO3
7	Kali Linux Attacks – Part1	Unit - 3	02 hours	CO3, & CO4
8	Kali Linux Attacks – Part2	Unit - 4	04 hours	CO2, & CO3
9	SSPT Practice Test -1Quiz	Unit - 4	02 hours	CO2, & CO4
10	Apply data mining tools for cyber security related data analysis	Unit - 4	04 hours	CO1,CO2, CO3, & CO4

Subject Code	**CE-662A**
Subject Title	**Advanced System Security**
Credit	**04**

TeachingScheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	03 monthly tests + 01 final evaluation + assignments for internal assessment
Total Marks	100
Prerequisite	Basic Operating System concepts; Programming language- preferably C

Objective:
To learn designing and building a secure operating system, ensuring the enforcement of system security goals and evaluating the OS w.r.t necessary and sufficient conditions.
This includes learning and understanding-

The security architectures of current operating systems

Distinct approaches to building secure operating systems and Challenges in implementation

Concept of virtualization

Explore a range of existing problems and tensions in modern systems' security

Course Outcome:

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.

Basics & Preliminaries	**Details:**	**Text Book**	**Hours**
Unit – I	**Security Principles:** CIA triad; Operating System Security goals, Trust model, Threat model; Protection system; Reference monitor concept. Distributed System Security Goals. **Access Control:** Discretionary protection system, Mandatory protection system, Authentication and Role Based Access Control, Authorization and Attribute Based Access Control, Rule-based access control.	Textbook1, Reference1	08
Unit – II	**Multics:** Multics security fundamentals, protection system models, vulnerability analysis. **Security in Commercial Operating Systems:** protection system, authorization, security analysis for Unix-like and Windows OS. Security in Distributed Systems.	Textbook1, Textbook2	10
Unit – III	**Verifiable Security Goals:** Information flow models, secrecy models, integrity models. **Secure Capability Systems:** Capability system fundamentals, Secure capability systems mechanisms.	Textbook1, Reference2	12

	Secure Virtual Machine Systems: Separation kernels, sandboxing, Multiple Independent Levels of Security.		
Unit – IV	**Attack vectors:** Memory exploits and other Firmware-based attacks, code based attacks; Return-to-libc Attacks, Spectre and Meltdown; shared library, buffer overflow attacks **Case Studies** (Security enhanced OS): STUDENT PRESENTATION & INTERACTIVE SESSIONs	Textbook1, Textbook2, Reference1	12

Textbooks

Jaeger, T., "Operating System Security", Morgan & Claypool (online), 2008.

Wenliang Du, "Computer & Internet Security: A Hands-on Approach", 1 May 2022

References

Matt Bishop, "Computer Security", Addison Wesley, 2002

Morrie Gasser: "Building a Secure Computer System"

Silberschatz and Galvin: "Operating System Concepts", Addison Wesley, 2006

Virgil Gligor's Lectures on Security Policies.

Lab Assignments

Lab 1	Overview of basic UNIX commands, Users management	Unit 1	02 Hrs	CO1 & CO4
Lab 2	Access Control management in Linux and Windows	Units 1 & 2	02 Hrs	CO1, CO2 & CO4
Lab 3	Main memory based vulnerabilities (E.g. Buffer Overflow; Return-oriented Programming)	Unit 4	04 Hrs	CO3 & CO4
Lab 4	Setting up confined execution environment (Sandboxes, Jailing)	Unit 3	04 Hrs	CO1, CO2 & CO4
Lab 5	Study and Set-up of Virtual Environment	Unit 3	02 Hrs	CO2 & CO4
Lab 6	Linux Kernel Compile and Implementing Linux Security Module	Unit 3	04 Hrs	CO2 & CO4
Lab 7-10	Mini Project: Code Injection || Binary Exploitation || Kernel Backdoors and Rootkits || Realization of (any of the) Attack Vectors	Units 1, 2, 3, 4	08 Hrs	CO1, CO2, CO3 & CO4

SubjectCode	**CE684**
Subject Title	**Digital Forensics**
Credit	**04**
TeachingScheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/weekTotal Contact hours 05 per week.
Evaluation Pattern	Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** One Final Evaluation at the End of the Term **50 Marks** Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100 Marks
Prerequisite	Knowledge of OS, Assembly Languages like Python, Number System and their Conversions, Internal Structure of CD/DVD.

Course Outcomes	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			
Syllabus Details	**Details**	**Text books/Reference books**	**Hrs**	**COs**
Unit I	Introduction to digital forensics Stages of Forensic: acquisition or imaging of exhibits, analysis and reporting standards Introduction to Computer Forensics: Digital Devices with rudimentary computing power Acquisition or imaging of Onboard Memory and Static Memory Introduction to legal issues, Analysis and Reporting Standards,Online and Live Forensics	Text Book1, R3	12	CO1, CO4
Unit 2	Forensic study of database and their metadata, database contents, log-files for creating timeline or recover relevant information	Text Book3	12	CO3, CO4
Unit III	MFT & Registry Hives Extraction from Windows OS through Tools and Scripts Data Carving Using Open Source Tools,Data Recovery and Secure deletion on Storage media. Evidence or Intrusion detection from internet logs, monitoring and analysis of network traffic.Internet of Things	Text Book2, R1	12	CO2, CO4
Unit IV	Recovery and Analysis of artifacts from Mobile Devices Information gathering and analysis using Social Network Analysis of artifacts from mobile devices,Social Network Artifacts Extraction and Analysis	Text Book2, R2	12	CO2, CO4

Text Book:

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, 1^{st} 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

Lab Assignments

Name of Experiments	Units	Hrs	Co’s
Perform Imaging and Analysis of Non-Volatile Memory using Open Source Tools in the absence of Write-Blockers.	I	02	CO1, CO4
Perform Imaging and Analysis of Non-Volatile Memory using EnCase/Other Open Source Tools With and Without Write Blockers.	I	02	CO1, CO4
Explore the Phases of Ethical Hacking in terms of implementing some attack.	I	02	CO1, CO4
Perform Imaging and Analysis of Volatile Memory using EnCase/Other Open Source Tools	I	02	CO1, CO4
MFT & Registry Hives Extraction from Windows OS through Tools and Scripts.	II	02	CO3, CO4
Recovering Deleted File from the File System	II	02	CO3, CO4
SystemHiding Data into Slack Space.	II	02	CO3, CO4
Data Recovery and Secure deletion on Storage media.	III	02	CO2, CO4
Data Carving Using Open Source Tools	III	02	CO2, CO4
Information gathering and network traffic analysis using TCP DUMP and WIN DUMP	III	02	CO2, CO4
Attacks and Forensics using IoT devices	IV	02	CO3, CO4
Social Network Artifacts Extraction and Analysis.	IV	02	CO3, CO4

Subject Code	**CE-664A**
Subject Title	**Network and Cloud Security**
Credit	**04**
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	03 monthly tests + 01 final evaluation + assignments for internal assessment
Total Marks	100
Prerequisite	Basic computer networking, operating systems and computer programming knowledge is required.
Objective: 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 Outcomes:

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)

Syllabus:

Syllabus Details		**Text Book**	**Hours**	**Outcome**
Unit 1	Introduction, OSI security Architecture, Security Principles, Attacks and Threats, Model of Network Security Security at Application Layer: Email Architecture, PGP, S/MIME	Text book 1 Chap 1, & 8	6	CO1
Unit 2	Security at Transport Layer: SSL Architecture, TLS, SET, HTTPS protocols Security at Network Layer, IPSec, VPN, ISKMP Firewall: Types of Firewalls, Firewall configuration, DMZ, UTMs	Text Book1, Chap 6 & 9**, 12**	12	CO1
Unit 3	Intrusion Detection and Intrusion Prevention Systems, Honeypots, Distributed IDS, Password Management Authentication: kerberos, X509, Authentication, PKI	Text Book 1 Chap 11 & 4	7	CO2
Unit 4	Wireless Security: Wireless LAN, 802.11 Standards, Security of WLAN Cloud Security: Cloud Computing, Security Issues and Challenges, Applications	Text Book 1 Chap 5, 7	9	CO2

Unit 5	DDoS : Direct, Reflector and Amplifier Attacks, TCP Syn Flooding, Countermeasures, Digital Attack Maps Malicious Software: Viruses, Worms, Ransomware etc, Anti-virus Architecture, Generation of Anti-Virus, Types of Viruses in network and cloud Network and cloud Reconnaissance, Traceroute, Port Scanning, ICMP Scanning, Sniffing, Probing Routers in cloud	Text Book 1 Chap 10 Text Book 2,3	9	CO3
Unit 6	Game Theory applications in Network Security Miscellaneous topics and current developments, Dark Web Network Security Observatory: Monitoring Networks	Research Papers & Ref 1	11	CO3

Text Book:

1. William Stallings, "Network Security Essentials", 6th Edition, Pearson Education, 2019.
2. B. Menezes, "Network Security and Cryptography", Cengage, 2013.
3. W. Du, "Computer and Internet Security: A Hands On Approach", 3rd Edition, 2022.

Reference Books:

1. T.Alpcan and T. Basar, "Network Security: A Decision and Game-Theoritic Apparoach", Cambridge University Press, 2010.
2. Bragg et al. "Network Security: The complete Reference", McGraw Hill, 2004
3. Seedlabs: https://seedsecuritylabs.org/ (last accessed on 12th June 2022).

Lab Assignments

Sl No	Lab Experiment	Unit	Hours	Outcome
1	Packet Sniffing and Spoofing Lab	1	2	CO1, CO4
2	TCP attacks Lab	2	2	CO1, CO4
3	Firewall Exploration Lab	2	2	CO1, CO4
4	VPN Lab	2	2	CO1, CO4
5	Wireshark Lab	5	2	CO3, CO4
6	Snort: Intrusion Detection Lab	3	2	CO2, CO4
7	CyberCiege Lab	1	2	CO1, CO4
8	OpenSSL Exploration Lab	2	2	CO1, CO4
9	Digital Attack Maps DOS lab	5	2	CO3, CO4
10	Cloud Computing Lab	4	2	CO2, CO4

Subject Code	CE694

Subject Title	**Cyber Physical Systems**
Credit	**04**
Type of Sub	- Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** One Final Evaluation at the End of the Term **50 Marks** Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100 Marks
Prerequisite	None. First 10 hours will be devoted for Prerequisite learnings related to basics of Databases (04 hours), Computer Networks (02 Hours), Operating System (02 Hours), Trends in evolutions of Compute-Devices (02 Hours)
Dept	CSE
Experts	Contribution from Academia/ R&D Org: Dr. Rituraj, ScG, CAIR Contribution from Industry: Dr Prashant Pansare, CEO & Founder, Rubiscape,
About the Course	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.

<table>
<tr><td></td><td></td></tr>
<tr><td>Course Outcomes</td><td>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.</td></tr>
<tr><td>Course Outcomes</td><td>Bloom’s Taxonomy:

Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze
Level-5 Evaluate; Level-6 Create</td></tr>
<tr><td></td><td>
<table>
<tr><th>CO Title</th><th>Level</th><th>Descriptor</th><th>Out come</th></tr>
<tr><td>CO1: Students will be able to understand the scope of applications of CPS.</td><td>L1, L2</td><td>Remember, Learn, Understand</td><td>20%</td></tr>
<tr><td>CO2: Students will be able to analyse the various components of CPS</td><td>L3, L4</td><td>Apply, Analyse</td><td>20%</td></tr>
<tr><td>CO3: Students will apply mechanisms to enable autonomous and self-organising techniques</td><td>L4, L5</td><td>Analyse, Evaluate</td><td>20%</td></tr>
<tr><td>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)</td><td>L5, L6</td><td>Evaluate, Create</td><td>40%</td></tr>
</table>
</td></tr>
<tr><td colspan="2">CO-PO : Course Outcome and Program Outcome Evaluation Metrics</td></tr>
<tr><td colspan="2">
<table>
<tr><th></th><th>PO1</th><th>PO2</th><th>PO3</th><th>PSO1</th><th>PSO2</th></tr>
<tr><td>CO1</td><td>Y</td><td></td><td></td><td>Y</td><td>Y</td></tr>
<tr><td>CO2</td><td>Y</td><td></td><td></td><td>Y</td><td>Y</td></tr>
<tr><td>CO3</td><td></td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td>CO4</td><td></td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>Summary of the Course Out Come</td><td>At the end of the course, a student will understand the concepts of CPS. Develop skills to relate a CPS as a feedback system along with its designing, modelling and implementation challenges. Evaluate the requirements to address emerging areas of digitization, AIML, and Secure environments.</td></tr>
<tr><td colspan="2">Syllabus Description</td></tr>
</table>

Basics & Preliminaries	Role of Basic and Advanced Data Structures in Data Models, Types of Data Models, Basic Dictionary Data Types; Algorithms and basics of analysis, OS & Algorithms in Parallel Environments. Protocols of Computer Networks preliminaries, Concerns for Data Security and Privacy	Cormen et al, Horowitz Sahani, Bipin Desai, Korth et al. Kurose Ross	10 Hours	CO1, PO1
Unit-1	CPS**:** Introduction Main Concepts, Challenges; Background role of Computer Networks, Data, Algorithms	Text Book-1, Ch-1	08 Hours	CO1, CO2, PO1
Unit-2	Self-organising Systems, Self-organisation in Natural Systems Inspiring Self-organising Software,	Text Book-1, Ch-2, 3	04 Hours	CO1, PO1
Unit-3	Agents and Multi-Agent Systems Computing trends, Data device proliferation, Confluence of trends	Text Book-1, Ch-4	06 Hours	CO1 CO2, PO1
Unit-4	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	Text Book-1, Ch-4, 5	06 Hours	CO3, PO2
Unit-5	Engineering Self-organising Systems, Middleware Infrastructures for Self-organising Pervasive Computing Systems	Text Book-1, Ch 5,6,7,8	06 Hours	CO3, PO2
Unit-6	CPS design Standards, Time Models, CPS Special Interest Groups and Mitre Commendations in Design and developments	Weblink References	06 Hours	C04, PO4
Unit-7	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.	Text book-1, Ch-8,9	06 Hours	CO1, CO4, PO1, PO3
Text Books	Text Books		Must Know	

(MUST Know)	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 (SHOULD Know)	Reference Book-1 “Principles of Cyber-Physical Systems” - Rajeev Alur, MIT Press, 2015 Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006 Kurose and Ross, Top Down Approach of Computer Networks, Prentice Hall, 8th Edition 2021.		Should Know	
Consortium, e-books and Web Link references (SHOULD/ Could Know)	https://iveybusinessjournal.com/publication/why-big-data-is-the-new-competitive-advantage/https://www.cdsaonline.org/cps-standard/ https://pages.nist.gov/cpspwg/ International Association for Automation Research Papers shared by the subject incharge		Should and May know	
Laboratory Assignments/ Demonstrations				
LAB Assignments	*Each student will work on unique case study. Will require approval of the same at the beginning. Report submission is essential for each Lab Assignment.			
1	Describe the Use Case*. Model the case study. Abstract.	Unit-1	02 hours	CO1
2	Modelling Tools exploration and implementation of the subsystems/ systems of the case study.	Unit-2	02 hours	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.	Unit 4 & 5	02 hours	CO4

	Develop the methods to audit and parameters of importance. Generate the incidence response reports.			
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	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

Subject Code	AM 607
Subject Title	**Mathematics for Engineers**
Credit	**04**
TeachingScheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	03 monthly tests + 01 final evaluation + assignments for internal assessment
Total Marks	100
Prerequisite	

Course offered from Mathematics Department, DIAT

Syllabus:

Elements of Probability and Statistics: Basic concepts of Probability, Discrete Probability Distributions (Binomial, Poisson etc.), Continuous Probability Distributions (Normal, Exponential, etc.,).

Components of Operations Research:

Introduction to Operations Research, Linear programming (Simplex Method, Revised Simplex Method, Dual simplex, Duality theory), Transportation Models.

Linear Algebra:

General (real) vector spaces, Subspaces, Linear Independence of Vectors, Basis and Dimension, Linear Transformations, Span, Norms, Orthogonal basis and Gram-Schmidt Orthogonalization.

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.

Transform Techniques :

Overview of Laplace transforms, Fourier Transforms, Z transform.

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

Text/References:

Advanced Engineering Mathematics, 11th Ed, 2010, Erwin Kreyszig, Wiley Eastern.
Linear Algebra and its Applications, 4th Ed., 2008, Gilbert Strang, Academic Press.
Numerical Methods for Scientists and Engineers, Joe D. Hoffman, Marcel Dekker Inc.
Numerical Methods for Engineers, Sixth Edition, Steven Chapra and Raymond Canale, McGraw-Hill Education
Elements of Numerical Analysis, 2nd Edition, Radhey S. Gupta**,** Cambridge University Press
Numerical Solutions of Partial Differential Equations: An Introduction, 2nd Ed., 2005, K. W. Morton, D. F. Mayers, Cambridge University Press.
Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.
Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
Differential Equations and Dynamical Systems, Texts in Applied Mathematics, L. Perko,

3rd Ed., Vol. 7, 2006, Springer Verlag,New York. .S. Gupta.. Calculus of Variation, Prentice Hall of India Pvt. Ltd.

Subject Code	**PGC-601**
Subject Title	**Research Methodology and IPR**
Credit	**02**
TeachingScheme	Lectures: 02 hours/week
Evaluation Pattern	03 monthly tests + 01 final evaluation + assignments for internal assessment
Total Marks	
Prerequisite	
Course Instructor	

Syllabus Contents:

Unit 1: 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 2: Effective literature studies approaches, analysis
Plagiarism, Research ethics,

Unit 3: Effective technical writing, how to write report, Paper
Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Unit 4: 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 5: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology.
Patent information and databases. Geographical Indications.

Unit 6: New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

References:

Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"
Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for
Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
Mayall, "Industrial Design", McGraw Hill, 1992.
Niebel, "Product Design", McGraw Hill, 1974.
Asimov, "Introduction to Design", Prentice Hall, 1962.

Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Elective-I/II

CE669 Reverse Engineering and Malware Analysis

Course Objectives:

The course introduces reverse engineering techniques and explores the techniques for detecting, analyzing, reverse engineering and eradicating malware.

Upon completion of the course, students should be able to:

- Have a good understanding of reverse engineering techniques and tools
- Identify the different types of malware analysis methods
- Setup an environment for malware analysis
- Recognize common malware characteristics

Pre-requisites: Assembly language programming, OS fundamentals.

Syllabus:

Introduction to reverse engineering, Low level software, Assembly language primer, Compilers, Execution Environments, Windows OS fundamentals, Executable file formats, Static & Dynamic reverse engineering, Reversing tools, Disassemblers, Debuggers, Decompilers, System monitoring tools, Reversing program binaries, Anti-reversing techniques, Breaking protections, Reversing '.NET', De-compilation, Introduction to malware, Software vulnerabilities – buffer overflow, integer overflow, vulnerabilities exploitation, mitigation; Return oriented programming; Reversing malware – Static & Dynamic malware analysis techniques, Packers & compression, Sandboxing executables& runtime analysis; Malware classification.

Text Book:

1. EldadEilam, "Reversing: Secrets of Reverse Engineering", Wiley publishing, 2005.

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. Erik Buchanan, Ryan Roemer, HovavShacham, and Stefan Savage. 2008. "When good instructions go bad: generalizing return-oriented programming to RISC."

CE683 Information Warfare

Prerequisites to study the subject - Students are required to gain knowledge of computer networking and basic concepts of Cyber Security.

Objective of the course/subject - 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.

Syllabus:

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, 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, 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), 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. D. Denning, "Information Warfare and Security", Addison-wesely, 1999.

Reference 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
5. NSA ANT Catalog: NSA's ANT Division Catalog of Exploits for Nearly Every, http://leaksource.info/2013/12/30/nsas-ant-division-catalog-of-exploits-for-nearly-every-major-software- hardware-firmware/
6. Research paper for study (if any) - White papers on cyberwarfare from IEEE/ACM/IBM sources.
7. Important website for reference & Study (if any) - ISACA website.

CE 689 Fault Tolerant Computing System

Syllabus

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 Book:

1. Koren and C. Mani Krishna, Fault-tolerant Systems, 1st edition, 2007, Morgan Kaufmann.

Reference Book:

1. D. P. Siewiorek and R. S. Swarz, Reliable Computer Systems - Design and Evaluation, 3rd edition, 1998, A.K. Peters, Limited.
2. D. K. Pradhan, ed., Fault Tolerant Computer System Design, 1st edition, 1996, Prentice-Hall.

CE 690 Parallel and Distributed Systems

Course Objective

To meet end-user, Administrator & Designer perspectives. Enhance analytical capabilities to evaluate a system.

About the Course**:** The study of Parallel and Distributed Systems investigates software architectures to support flexible parallel and distributed applications, which can adapt themselves for execution in dynamically changing, heterogeneous environments. The study targets the diverse environments ranging from scalable clusters of commodity workstations to dynamic aggregations of computing and information resources, emphasizing the interactions between hardware, operating systems, and applications. The study includes efforts to build fault- tolerant programming systems, compiler-assisted object caching systems, application-structuring mechanisms for adaptation in dynamic environments, and transparent secure distribution middleware for general-purpose applications. These projects encompass a gamut of approaches from fundamental research through prototypes, up to working usable systems.

Pre-requisites: CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations, Fundamental Computer architecture, programming environments, computer networks

Syllabus:

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 book:

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.

Papers:

1. Fox, Geoffrey C. "Large scale data analytics on clouds." *Proceedings of the fourth international workshop on Cloud data management*. ACM, 2012.
2. Shanker, Udai, Manoj Misra, and Anil K. Sarje. "Distributed real time database systems: background and literature review." *Distributed and parallel databases* 23.2 (2008): 127-149.
3. Research Papers discussed in the classroom discussions.

CE 691 SECURE WIRELESS SENSOR NETWORKS

Background: Wireless Sensor networks (WSN) is an emerging technology and have great potential to be employed in critical situations like battlefields and commercial applications such as building, traffic surveillance, habitat monitoring and smart homes and many more scenarios. One of the major challenges wireless sensor networks face today is security. While the deployment of sensor nodes in an unattended environment makes the networks vulnerable to a variety of potential attacks, the inherent power and memory limitations of sensor nodes makes conventional security solutions unfeasible. The sensing technology combined with processing power and wireless communication makes it profitable for being exploited in great quantity in future. The wireless communication technology also acquires various types of security threats.

Objective**:** To meet End-User, Network-Administrator and Network-Designer perspectives

Prerequisite: Computer Networks Fundamentals, Programming,

Syllabus:

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 Book:

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

Research Paper References:

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.

Tutorials:

a. Routing techniques: Overview of Proactive and reactive routing protocols, significance of *a hop* in adhoc networks
b. Flooding, Gossiping, Zonal Routing Protocols ZRP, Hybrid Routing, TTL significance with respect to routing protocols
c. Impact of hardware and software on Battery Performances/Utilisation
d. IEEE 802.15.4: A study, Features, Types of Devices FFD (PAN coordinators, Coordinators), RFDs Reduced Function Devices, Network Setup process & parameters in Consideration, Programming Strategies to suit the standards, MAC and PHY structure
e. Demo 1: Controlling DIOs. Demonstrate the usage of DIO using LEDs. Learning how to handle data sampling period.
f. Demo 2. Reading data from a single IoT device. Interpretation of data.
g. Demo 3: Create a broadcast wireless network and capture the traffic generated by the participating nodes.
h. Demo 4. Creating a multi-hop network using MBR routing.
i. Understanding MBR & LBR (MAC Based Routing and LBR Level-Based Routing)
j. Understanding exiting API, Libraries & its association with pre-existing demonstration codes.

CE667 Trustworthy Computing

Course Prerequisites**:**Basic understanding of Boot Process, Shell Programming and Formal Methods, Fundamentals of OS.

Course Objectives**:**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.

Syllabus:

Introduction to trusted computing, Techniques for recording platforms state: Recording code identity, Recording dynamic properties. 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, Research solutions without hardware support. Challenges in bootstrapping trust in secure hardware: Problem definition, Potential solutions. Validating the process. 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.

Reference Books:

1. DynamicsofaTrustedPlatform:ABuildingBlockApproach,DavidGrawrock,IntelPress;1stedition, ISBN:1934053171.

CE 692 Computational Geometry and Applications

Pre-requisites**:**

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.

Syllabus:

Geometric primitives, Line intersection, randomized incremental concepts, Triangulation and visibility, Linear programming in two and three dimensions, Orthogonal range searching, Point location and Binary Space Partitions, Voronoi diagrams and Delaunay triangulation, Convex hulls, Non-orthogonal range searching

Text Book:

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

CE 694 Big Data Analysis & Algorithms

Course Objective

To meet end-user, Administrator & Designer perspectives, develop skill sets to be resourceful in the area of knowledge, information systems. Enhance analytical capabilities to evaluate a domain specific technical and expertise areas. Multi-Disciplinary Course useful to any engineering discipline who use a computer.

About the Course**:**The use of Big Data is becoming a crucial way for leading companies to 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.

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 SophosLabs, 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.

Intended Audience:CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations

Pre-Requisites: Basic programming knowledge, Data Structure, Programming, Statistical Techniques

Course Contents:

Unit I : Introdution to big data analysis: Evolution of data, data streams, structured & unstructured data, database models, graph data, normalizations

Unit II: Big data analytics platforms: Architectures, Frameworks that enable big data analytics

Unit III: Big data analytics storage & processing: Data Preprocessing, , Multi-Dimensional Data Models, Data Warehousing OLTPS, OLAPS, Data Warehouse Architectures, Datacube Computations, Big Data Mining Frequent Patterns, Big Data Associations & Correlations, Classifications & Predictions, Clustering Techniques & Analysis, Mining Data Streams, Graph Mining Mining Spatial & Temporal Objects, Predictive Analysis, Ad Hoc Queries, Web Analytics

Unit IV: Algorithms for massive data sets, Algorithms for SISD, SIMD environments, Linked Big Data Analysis – Graph Computing and Network Science, Big Data Visualization, Big Data Mobile Applications, Large- Scale Machine Learning, Big Data Analytics on Specific Processors, Hardware and Cluster Platforms for Big Data Analytics, Big Data Next Challenges – IoT, Cognition, and Beyond

Unit V: Big data analytics tools, HDFS, NOSQL, SQL environments

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

References:

1. Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006
2. Introduction To Algorithms, Thomas H. Cormen, Charles E. Leiserson, Ronaldo L. Rivest, Clifford Stien 2nd Edition Course
3. Research Papers discussed in the classroom discussions.

Course links & References:

1. https://iveybusinessjournal.com/publication/why-big-data-is-the-new-competitive-advantage/
2. https://www.datameer.com/company/datameer-blog/challenges-to-cyber-security-and-how-big-data-analytics-can-help/
3. https://www.iss.nus.edu.sg/executive-education/discipline/detail/analytics-and-intelligent-systems

CE 695 Cyber-Physical & Self-Organising Systems

Brief About the Subject**:** 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).

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 and Control environments.

Pre-requistes: CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations, Theoretical knowledge of Computer Science and Engineering

Syllabus:

Unit I: CPS: Introduction Main Concepts, Challenges; Background role of Computer Networks, Data, Algorithms

Unit II: Self-organising Systems, Self-organisation in Natural Systems Inspiring Self-organising Software,

Unit III: Agents and Multi-Agent Systems Computing trends, Data device proliferation, Confluence of trends

Unit IV: Technological and economic drivers Self-organisation Mechanisms, Stigmergy , Gossip , Trust and Reputation for Successful Software Self-organisation,Cooperation , Immune Systems, Holonic Multi-Agent Systems Engineering Artificial Self-organising Systems,

Unit V: Engineering Self-organising Systems, Middleware Infrastructures for Self-organising Pervasive Computing Systems

Unit VI: Applications of Self-organising Software, Self-organisation in Constraint Problem Solving, Adaptive Trust Management, Security in Artificial Systems

Text Books:

1. Self Organising Software from Natural to artificial Adaptation, Di- MarzoSerugendo, ;Gleizer, M-p; Karageorgos, A (Eds), 2011, XVIII,462P; Hardcover ISBN:978-3642-17347-9
2. “Principles of Cyber-Physical Systems” - Rajeev Alur, MIT Press, 2015
3. Research Papers discussed in the classroom discussions.

Reading assignments:

1. **Introduction:** Brief history of CPS. Motivating problems in CPS.
2. K. Kim and P.R. Kumar, \CyberPhysical Systems: A Perspective at the Centennial," Proceedings of the IEEE , vol. 100, May 2012, p. 1287{1308.
3. E. Lee, \Cyber Physical Systems: Design Challenges", Proceedings of the IEEE Symposium on Object Oriented Real-Time Distributed Computing (ISORC), 2008, p. 363{369.
4. R. Rajkumar, \A Cyber-Physical Future,"Proceedings of the IEEE, vol. 100, May 2012, p. 1309{1312.
5. S. Barnum, S. Sastry, and J. Stankovic, \Roundtable: Reliability of Embedded and Cyber-Physical Systems," IEEE Security and Reliability , September / October 2010, p. 27{32.

Modeling: Continuous systems and discrete event systems.

6. Lygeros, Sastry, and Tomlin, Chapter 2
7. P. Derler, E. Lee, and A. Sangiovanni-Vincentelli, \Modeling Cyber-Physical Systems," Proceedings of the IEEE, Vol.100, no. 1, January2012, p.13{28.

Control over networks

8. R. Alur, A. D'Innocenzo, K. Johansson, G. Pappas, and G. Weiss, \Compositional Modeling and Analysis of Multi-Hop Control Networks," IEEE Transactions on Automatic Control, vol. 56, no. 10, October 2011, p. 2345{2357.
9. J. Hespanha, P. Naghshtabrizi, and Y. Xu, \A Survey of Recent Results in Networked Control Systems," Proceedings of the IEEE, vol. 95, no. 1, January 2007, p. 138{162.
10. Pajic, R. Mangharam, G. Pappas, and S. Sundaram, \Topological Conditions for In-Network Stabilization of Dynamical Systems,"IEEE Journal on Selected Areas in Communications, vol. 31, no. 4, April 2013.
11. G. Hackmann, W. Guo, G. Yan, Z. Sun, C. Lu, and S. Dyke, \Cyber-Physical Codesign of Distributed Structural Health Monitoring with Wireless Sensor Networks,"IEEE Transactions on Parallel and Distributed Systems , vol. 25, no. 1, p. 63{72, January 2014.

Stability of Hybrid and Switched Systems

12. R. A. Decarlo, M. S. Branicky, S. Pettersson, and B. Lennartson, \Perspectives and Results on the Stability and Stabilizability of Hybrid Systems," Proceedings of the IEEE ,vol. 8, no. 7, p. 1069{1082, July 2000.
13. D. Liberzon and A. S. Morse, \Basic problems in stability and design of switched systems," IEEE Control Systems Magazine , vol. 19, no. 5, pp. 59{70, October 1999.
14. M. Branicky, \Multiple Lyapunov functions and other analysis tools for switched andhybrid systems," IEEE Transactions on Automatic Control , vol. 43, no. 4, p. 75{482, April 1998.
15. J. Hespanha, \Uniform Stability of Switched Linear Systems: Extensions of LaSalle'sInvariance Principle," IEEE Transactions on Automatic Control , vol. 49, no. 4, p.470{482, April 2004

Reference Links: https://www.cs.cmu.edu/~aplatzer/course/fcps16.html

CE 69F Theory of Computation

Syllabus:

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 Book:

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.

CE 697 Biometric Security

Course Objectives:

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 students 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.

Syllabus:

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 Book:

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

CE 698 Multimedia Security

Course Objectives**:**

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.

Prerequisites: Basic computer programming knowledge is required.

Syllabus:

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 Book:

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
2. Frank Y. Shih, “Multimedia Security: Watermarking, Steganography, and Forensics”, March 29, 2017 by CRC Press ISBN 9781138072541
3. Sunita Dhavale, “Advanced Image-Based Spam Detection and Filtering Techniques”, IGI Global, Hershey, PA, USA, March 2017.
4. Shigno Lian, “Multimedia Content and Encryption: Techniques and Applications”, 2017 by Auerbach Publication ISBN 9781420065275

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

CE 699 : Internet of Things

Objective

To meet end-user, Network-Administrator & Designer perspectives, develop skill sets to be resourceful in the area of Cyber-Security. Enhance analytical capabilities to evaluate a deployment and realisation.

About the Course:

The Internet of Things (IoT) is predicted to be the single most important factor impacting fundamental business logic in the coming decades. Government, academia, and industry are involved in different aspects of research, implementation, and business with IoT. IoT cuts across different application domain verticals ranging from civilian to defence sectors. These domains include agriculture, space, healthcare, manufacturing, construction, water, and mining, which are presently transitioning their legacy infrastructure to support IoT. Today it is possible to envision pervasive connectivity, storage, and computation, which, in turn, gives rise to building different IoT solutions. IoT-based applications such as innovative shopping system, infrastructure management in both urban and rural areas, remote health monitoring and emergency notification systems, and transportation systems, are gradually relying on IoT based systems. Therefore, it is very important to learn the fundamentals of this emerging technology & enable the students to anticipate and acknowledge the security concerns and vulnerabilities in the cyberspace. The impact of poor IoT security is being felt like a monsoon as these devices are compromised and then used to flood targets with DDOS traffic. As we move forward into this IoT era, it is imperative that we take steps as individuals to protect our Networks.

Intended Audience:

CSE, IT, ECE, EE, Robotics, Instrumentation Engg, Industrial Engineering, Modelling & Simulations
Pre- Requisites : Basic programming knowledge

Course Contents:

Unit I:

Introduction to Internet of Things, Definition and Characteristics of IoT, Physical Design of IoT, IoT Protocols, IoT communication models, IoT Communication APIs

Unit II

IoT enablingTechnologies, Wireless Sensor Networks, Cloud Computing, Big data analytics, Communication protocols, Embedded Systems, IoT Levels and Deployment Templates, Domain Specific IoTs: Home, City, Environment, Energy, Retail, Logistics, Agriculture, Industry, health and Lifestyle

Unit III

IoT and M2M, Software defined networks, network function virtualization, difference between SDN and NFV for IoT, Basics of IoT System Management with NETCOZF, YANG, NETCONF, YANG, SNMP NETOPEER

Unit IV

IoT physical end devices & end points, IoT Physical Servers & Cloud offerings, Software environments, NEO, Security

Text Book

1. "Internet of Things: A Hands-on Approach", by Arshdeep Bahga and Vijay Madisetti (Universities Press), 2014

References

2. "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by Pethuru Raj and Anupama C. Raman (CRC Press)
3. "Designing the internet of things", McEwen, Adrian, and Hakim Cassimally. John Wiley & Sons, 2013.
4. Research Papers discussed in the classroom discussions.

CE604 COMPUTATIONAL INTELLIGENCE

Course Objectives**:**
The course goal is to make students familiar with basic principles of various computational methods of computational intelligence (CI) like nature-inspired methods (neural nets, evolutionary algorithms), fuzzy systems, as well as various probabilistic methods under uncertainty (e.g. Bayesian models) and machine learning methods (e.g. reinforcement learning). After the course the students will be able to conceptually understand the important terms and algorithms of CI, such that they would be able to choose appropriate method(s) for a given task.

Prerequisites**:** Basic image processing knowledge/computer programming knowledge is required.

Syllabus:

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 Book:

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 & Int
5. elligent System", Oxford
6. ZM Zurada (1992), "Introduction to Artificial Neural Systems", West Publishing Company
7. Timothy J Ross (2004), "Fuzzy Logic with Engineering Applications", John Wiley & Sons Ltd.

<u>CE632 Computer Vision</u>

Subject Code	**CE632**
Subject Title	**Computer Vision**
Credit	**04**
Type of Subject	-Core (MTech in CSE) -Professional Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	. Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** . One Final Evaluation at the End of the Term **50 Marks** . Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100 Marks
Prerequisite	Statistical techniques, Linear algebra and computer programming knowledge is required.
Dept	CSE
Course Objectives	To introduce students the fundamentals of image formation; To introduce students the major ideas, methods, and techniques of computer vision and pattern recognition; To develop an appreciation for various issues in the design of computer vision and object recognition systems; and To provide the student with programming experience from implementing computer vision and object recognition applications.
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create

	CO Title	**Level**	**Descriptor**
	CO1: Students will be able to understand and apply image processing techniques including filtering operations, thresholding techniques, edge detection techniques etc. (PO1, PO2, PO3, PSO2)	L1, L2	Remember, Understand
	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)	L3	Remember, Understand Analyse
	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)	L3	Remember, Understand Analyse

	CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in computer vision related domain. (PO1, PO2, PO3, PSO2)	L4	Apply, Analyse	
Syllabus Description				
Basics & Preliminaries	Details	Books & References	Duration	COs
Unit-1	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	Textbooks - 1	12L	CO1
Unit-2	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 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	Textbooks - 2	12L	CO2
Unit-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	Textbooks - 2,3	12L	CO2
Unit-4	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	Textbooks/ References -4-8	12L	CO3
	LAB/ Assignments/Student Presentations [2T/P per week]		02L/Week	CO4
Text Books	E. R. Davies, “Computer & Machine Vision”, Fourth Edition, Academic Press, 2012. R. Szeliski, “Computer Vision: Algorithms and Applications”, Springer 2011. Simon J. D. Prince, “Computer Vision: Models, Learning, and Inference”, Cambridge University Press, 2012. Mark Nixon and Alberto S. Aquado, “Feature Extraction & Image Processing for Computer Vision”, Third Edition, Academic Press, 2012.			

Reference Books	D. L. Baggio et al., "Mastering OpenCV with Practical Computer Vision Projects", Packt Publishing, 2012. Jan Erik Solem, "Programming Computer Vision with Python: Tools and algorithms for analyzing images", O'Reilly Media, 2012. Sunita Vikrant Dhavale, "Advanced Image-based Spam Detection and Filtering Techniques", IGI Global, 2017 Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/ NVidia sources.			
Laboratory Assignments/ Demonstrations				
1	Introduction to Digital Image Processing using python	Unit -1	02 hours	CO1, CO2,CO3 , & CO4
2	Study and Implement Image Transformation Techniques	Unit -1	02 hours	CO1, CO3, & CO4
3	Study and Implement Image Transformation Techniques	Unit -1	02 hours	CO2, CO3, & CO4
4	Study and Implement Edge Detection Techniques	Unit -1	02 hours	CO1, CO3, & CO4
5	Study and Implement Image Thresholding Transform	Unit -1	04 hours	CO1, & CO4
6	Study and Implement Morphological Operations	Unit -2	02 hours	CO2, & CO3
7	Study and Implement Harris Corner Point Detection	Unit -2	02 hours	CO3, & CO4
8	Study and Implement SIFT	Unit -3	04 hours	CO2, & CO3
9	Mini assignment: Apply CV techniques to solve any real world problem/ Presentations	Unit -4	04 hours	CO2, & CO4
10	CV Practice Test -1Quiz/ Presentations	Unit -4	02 hours	CO1,CO2 , CO3, & CO4

E 70A Formal Specification and Verification of Programs

Objectives:

To study methods and techniques for stating and proving the correctness statements. Studying Mathematical Logic (Symbolic Logic), Mathematical models for programs. (Programming Language Semantics) and Justification of the verification techniques.

On successful completion of the module, the students

- should have a good knowledge and understanding of soundness, correctness of static analysis.
- should be able to understand the use of logic as a formal language for the specification of systems.
- understand the use of symbolic execution, and the main verification techniques used in symbolic model checking, and be able to verify simple systems
- study some of the issues that arise in deploying these techniques in practice, and solution strategies for them.

Syllabus

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 Reference:

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

CE70B Advanced Algorithms

Syllabus:

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

Laboratory Work:

Total V Practical Assignments. Lab Assignment based on each Unit.

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

CE 700 Quantum Computing

About this Course

"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.

Prerequisites are complex numbers and linear algebra

Course Contents:

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 Book:

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.

References**:** Research Papers as discussed in the class room.

CE 70E Machine Learning in Python

Course Objectives**:**

This course examines the tools and techniques required for learning machine learning algorithms. This course will provide an introduction to the subject and its various applications. Student will learn to implement ML algorithms in python for solving various problems.

Prerequisites**:** basics of probability & statistics is required.

Syllabus:

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.

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 network. UNIT VII Clustering: k-means, Gaussian mixture model.

Text/Reference 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

CE 70G Blockchain Technology

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.
Pre-requisite: Expertise in Programming, Basic Knowledge of Computer Security, Cryptography, Networking. Syllabus:

Unit1: Basic Cryptographic primitives used in Blockchain – Secure, Collison-resistant hash functions, digital signature, public key cryptosystems, zero-knowledge proof systems

Unit2: Basic Distributed System concepts – distributed consensus and atomic broadcast, Byzantine fault-tolerant consensus methods.

Unit3: Basic Blockchain – concepts to Bitcoin and contemporary proof-of-work based consensus mechanisms, operations of Bitcoin blockchain, crypto-currency as application of blockchain technology

Unit4: Hyperledger fabric platform- Decomposing the consensus process , Hyperledger fabric components, Chaincode Design and Implementation Hyperledger Fabric

Unit5: Beyond Cryptocurrency – applications of blockchain in cyber security, integrity of information, E-Governance and other contract enforcement mechanisms

Unit6: Security and Research Aspects Text/Reference Books:
1. "S. Shukla, M. Dhawan, S. Sharma, S. Venkatesan, 'Blockchain Technology: Cryptocurrency and Applications', Oxford University Press, 2019.
2. Josh Thompson, 'Blockchain: The Blockchain for Beginnings, Guild to Blockchain Technology and Blockchain Programming', Create Space Independent Publishing Platform, 2017.

CE682 Secure Software Engineering

Course Objectives**:**
Students will acquire an understanding of the fundamental concepts for developing secure systems
- Introduce security requirements, Security Policies, Architecture of Secure Software and Boot Integrity
- Attacker models
- Fundamentals of data protection and privacy.

Course Prerequisites:
C programming and debugging. Basic concept of Operating Systems.

Syllabus **:**

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,

Text / Reference 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.

CE639 - Practical Machine Learning

Subject Code	**CE639**
Subject Title	**Practical Machine Learning**
Credit	**04**
Type of Subject	-Core (MTech in CSE) -Professional Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** One Final Evaluation at the End of the Term **50 Marks** Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100 Marks
Prerequisite	Knowledge of Statistical techniques, Linear algebra and computer programming knowledge is required.
Dept	CSE
Course Objectives	To provide the knowledge of Python programming language as it applies to data analytics. Skills will be developed for Data Analysis with Python and develop product in python. Student will learn various ML techniques including Supervised, unsupervised classification and regression analysis, Artificial Neural Networks, etc. Student will learn Python Programming for implementing these algorithms on standard datasets

Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create		
	CO Title	**Level**	**Descriptor**
	CO 1 - Students will be able to understand ML paradigms and various Supervised, unsupervised classification and regression analysis methods. (PO1,PO2, PO3, PSO2)	L1, L2	Remember, Learn, Understand
	CO2: Students will be able to understand various ML algorithms like and analyse their applications in real world (PO1,PO2, PO3, PSO2)	L2	Remember, Learn, Understand
	CO3: Students will be able to understand advanced ML algorithms and techniques etc. (PO1,PO2, PO3, PSO2)	L3	Remembering, Understanding, Analysing
	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)	L4	Applying, Analysing

Syllabus Description

Basics & Preliminaries	Details	Books & References	Duration	COs
Unit-1	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	Textbooks - 1,2	12 Hrs	CO1
Unit-2	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	Textbooks - 2,3	12 Hrs	CO2

Unit-3	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.	Textbooks - 2,3,4	12 Hrs	CO2
Unit-4	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	Textbooks - 4-5, / References - 1-4	12 Hrs	CO3
	LAB/ Assignments/Student Presentations [2T/P per week]	Textbooks - 4-5, / References - 1-4	02 Hrs/week	CO4
Text Books (MUST Know)	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 (SHOULD Know)	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.			

Laboratory Assignments/ Demonstrations

1	Study and implement algorithms for data pre-processing and data cleaning	Unit -1	02 hours	CO1, CO3, & CO4
2	Study and implement algorithms for data feature selection reduction.	Unit -1	02 hours	CO1, CO3, & CO4
3	Study and Implement Linear Regression Algorithm for any standard dataset	Unit -2	02 hours	CO2, CO3, & CO4
4	Study and Implement unsupervised clustering Algorithms for any standard dataset	Unit -3	02 hours	CO1, CO3, & CO4
5	Study and Implement KNN for any standard dataset	Unit -3	04 hours	CO1, & CO4

6	Study and Implement ANN for any standard dataset	Unit -3	02 hours	CO2, & CO3
7	Study and Implement PCA for any standard dataset	Unit -3	02 hours	CO3, & CO4
8	Case Study: Use of ML along with Fuzzy Logic/ GA/PSO/ACO to solve real world Problem	Unit -4	04 hours	CO2, & CO3
9	9 Mini assignment: Apply ML to solve any real world problem	Unit -4	04 hours	CO2, & CO4
10	ML Practice Test – 1 Quiz	Unit - 1,2,3,4	02 hours	CO1,CO2, CO3, & CO4

Elective-III/IV

	AM 625	Digital Image Processing
	AM 628	Computational Number Theory and Cryptography
	EE 612	Advanced Wireless Communication
	EE 613	Electronic Warfare
	EE 618	DSP System Design
	TM 609	System Engineering
	TM 611	Software Projects Management

M.Tech Computer Science & Engineering (Artificial Intelligence)

Course Structure 2022-2024

Brief Description

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.

Pre-requisites/Eligibility

Scholarship Students Category: 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.

Sponsored Students Category: Minimum CPI of 6.5 or 60% of marks or first class in qualifying degree. Bachelor degree in Engineering/Technology or Equivalent in any Discipline.

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.

Semester I

Sr. No.	**CourseCode**	**Course**	**Contact Hours / Week**		**Credits**
			L	T/P	
1	CE694	Big Data Analysis and Algorithms	3	1	4
2	CE606A	Software Engineering & System Modelling	3	1	4
3	CE638	Foundations of AI	3	1	4
4	CE639	Practical Machine Learning	3	1	4
5	CE634	Natural Language Processing	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

Sr. No.	**CourseCode**	**Course**	**Contact Hours / Week**		**Credits**
			L	T/P	
1	CE631	Deep Learning	3	1	4
2	CE632	Computer Vision	3	1	4
3		**Elective I**	3	1	4

4		**Elective II**	3	1	4
5		**Elective III**	3	1	4
6		**Elective IV**	3	1	4
7	PGC-602	Audit 1 and 2	2	0	0
		Total	**18**	**6**	**24**

List of Audit Courses (Applicable for Sem - II):

Sr.No.	Course Code	Course
	PGC-602	English for Research Paper Writing
.		Disaster Management
.		Sanskrit for Technical Knowledge
.		Value Education
.		Constitution of India
.		Pedagogy Studies
.		Stress Management by Yoga
.		Personality Development through Life Enlightenment Skills

List of Open Electives Semester-II

Sr. No.	Course Code	Course
	CE-695A	Cyber Physical Systems
	CE664A	Network and Cloud security
	CE630	Virtual Reality
	CE665A	Security Audit and Penetration Testing
	CE633	Pattern Recognition
	CE691	Secure Wireless Sensor Networks
	CE699	Internet of Things
	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.		

COURSE CURRICULUM
SEMESTER I CORE COURSES

Subject Code	**CE694**

Subject Title	Big Data Analysis & Algorithms
Credit	**04**
Type of Subject	-Core (MTech in CSE) -Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	. Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** . One Final Evaluation at the End of the Term **50 Marks** . Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100 Marks
Prerequisite	None. First 10 hours will be devoted for Prerequisite learnings related to basics of Databases (04 hours), Computer Networks (02 Hours), Operating System (02 Hours), Trends in evolutions of Compute-Devices (02 Hours)
About the Course	The use of Big Data is becoming a crucial way for leading companies to 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. **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.
Course Outcomes & Objective	To meet end-user, administrator & system designer perspectives, develop skill sets to be resourceful in building and handling knowledge & information systems. Enhance analytical capabilities to evaluate a domain specific and

<table>
<tr><td></td><td>technical area. Multi-Disciplinary Course useful to any engineering discipline who use computer.
To educate the stakeholders on the growth of importance of information security. Along with personal utilization of systems, the privacy matters in the government, enterprise arenas. The study will significantly broaden the scope of individuals who must be aware of relevant issues as part of their work.</td></tr>
<tr><td>OBE Course Outcomes</td><td>Bloom’s Taxonomy:

Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create</td></tr>
<tr><td></td><td>
<table>
<tr><th>CO Title</th><th>Level</th><th>Descriptor</th><th>Expected Outcome</th></tr>
<tr><td>CO1: Student will be able to examine and identify Data Models for various applications</td><td>L1, L2</td><td>Remember, Understand Learn,</td><td>20%</td></tr>
<tr><td>CO2: Student will be able to apply data abstraction & normalisation techniques to handle volume and veracity</td><td>L3, L4</td><td>Apply, Analyse</td><td>20%</td></tr>
<tr><td>CO3: Student will be able to analyze & apply multi-dimensional data models for complex scenarios</td><td>L4, L5</td><td>Analyse, Evaluate</td><td>20%</td></tr>
<tr><td>CO4: Student will be able to evaluate the system requirements and propose solutions using various data models to cater special application requirements & to form a base to apply Data Mining & AIML techniques.</td><td>L5, L6</td><td>Evaluate, Create</td><td>40%</td></tr>
</table>
</td></tr>
<tr><td colspan="2">CO-PO : Course Outcome and Program Outcome Evaluation Metrics</td></tr>
<tr><td colspan="2">
<table>
<tr><th></th><th>PO1</th><th>PO2</th><th>PO3</th><th>PSO1</th><th>PSO2</th></tr>
<tr><td>CO1</td><td>Y</td><td></td><td></td><td>Y</td><td>Y</td></tr>
<tr><td>CO2</td><td>Y</td><td>Y</td><td></td><td>Y</td><td>Y</td></tr>
<tr><td>CO3</td><td></td><td>Y</td><td>Y</td><td></td><td>Y</td></tr>
<tr><td>CO4</td><td></td><td></td><td>Y</td><td></td><td>Y</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>Summary of the Course OutCome</td><td>At the end of the course, a student will understand the concepts of data models. Use data models. Evaluate requirements to address emerging areas of data handling with the growing needs. Broadly defined roles. Knowledge of enabling systems. Conducive environment building for data analysts. Data engineering to handle the data at public and private sectors while complying with the data policies to be professionals who understand structured and unstructured data and the challenges to handle them.</td></tr>
</table>

Syllabus Description				
Basics & Preliminaries	Types of Data Models, Role of Basic and Advanced Data Structures in Data Models, Basic Dictionary Data Types; Algorithms and basics of analysis, OS & Algorithms in Parallel Environments. Protocols of Computer Networks preliminaries, Concerns for Data Security and Privacy	Cormen et al, Horowitz & Sahani, Bipin Desai, Korth et al. Kurose Ross	10 Hours	CO, PO1
Unit-1	Introdution to big data analysis: Evolution of data, data streams, database models, graph data, normalizations, structured & unstructured data,	Text Book-1, Ch-1	08 Hours	CO1, CO2, PO1
Unit-2	Architectures, Adoption, Frameworks that enable big data analytics, Multi-Dimensional Data Models, Data cube Computations	Text Book-1, Ch-2, 3	04 Hours	CO1, PO1
Unit-3	Data Preprocessing, Data Warehousing OLTPS, OLAPS, Data Warehouse Architectures, Big Data Mining Frequent Patterns, Big Data Associations & Correlations, Classifications & Predictions, Clustering Techniques & Analysis, Mining Data Streams, Graph Mining, Mining Spatial & Temporal Objects, Predictive Analysis, Ad Hoc Queries, Web Analytics	Text Book-1, Ch-4	06 Hours	CO1 CO2, PO1
Unit-4	Algorithms for SISD, SIMD environments, Linked Big Data Analysis – Graph Computing and Network Science, Big Data Visualization, Big Data Mobile Applications, Large-Scale Machine Learning, Big Data Analytics on Specific Processors, Hardware and Cluster Platforms for Big Data Analytics, Big Data Next Challenges – IoT, Cognition, and Beyond	Text Book-1, Ch-4, 5	06 Hours	CO3, PO2
Unit-5	Big Data Storage & Processing Concepts Relational database technology, Parallel and Distributed Processing capabilities, Clouds, MapReduce Framework	Text Book-1, Ch 5,6,7,8	06 Hours	CO3, PO2, PO3
Unit-6	Database Auditing Models Technical Audit Environment, Process, Objectives, Classification Types, Incidence Reports, Level of escalations.	Weblink References	06 Hours	CO4, PO2, PO3

	Application Data Audit: DML Action Audit; Triggers; Fine-Grained Auditing FGA; Application Errors; PL-SQL Environments, Audit DB Activities			
Unit-7	Big data analytics tools, HDFS, NOSQL, SQL environments Project Cases Big data, Big Data Security: Online Databases; CSV files to Structured Environments, SCADA, IoTs,	Text Book-1, Ch-8	06 Hours	CO1, CO4, PO1, PO3
Text Books (MUST Know)	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		Must Know.	
Reference Books (SHOULD Know)	Reference Book-1 Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006		Should Know.	
Consortium, e-books and Web Link references (SHOULD/ Could Know)	https://iveybusinessjournal.com/publication/why-big-data-is-the-new-competitive-advantage/ https://www.datameer.com/company/datameer-blog/challenges-to-cyber-security-and-how-big-data-analytics-can-help/ https://www.iss.nus.edu.sg/executive-education/discipline/detail/analytics-and-intelligent-systems W3.org Meity.gov.in SIGSAC SIGSEC acm.org Isca-speech.org Issa.org Oracle.com/database/ . Thelawreviews.co.uk . Data Security Council of India (DSCI) . prsindia.org iso.org ISO/IEC 27000/27001/27002		Should and Could Know.	

Laboratory Assignments/ Demonstrations				
LAB Assignments	*Each student will work on unique case study. Will require approval of the same at the beginning. Report submission is essential for each Lab Assignment.			
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
8	Create model and implement any one security feature to demonstrate data security concern & mitigation.	Unit 7	02 hours	CO4
9	Assigned NOSQL Environment Study and Presentation.	Unit 1 to 7	Sem	CO4
10	Mini-project. Implementation and Demonstration. Report Submission is essential	Unit 1 to 7	Sem	CO4

Course Code: CE606A	
Course Title: Software Engineering & System Modelling	
Credit: 4	
Evaluation Pattern -	03 – monthly test + 01 Final Evaluation

Prerequisite: C programming and debugging concepts, basic concepts of operating systems.

Objective: Major objective is to learn basic principles of Software Engineering and Design, which can facilitate the resource efficient model of the Software Systems.

Course Outcome-

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

Unit	Syllabus Details	Outcome
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.	CO2, & CO4

Textbooks:
Software Engineering- Pankaj Jalote, TMH
Software Engineering- Ian Sommerville , Pearson
Craig Larman, "Applying UML and Patterns: An Introduction to object-oriented Analysis and Design and iterative development”, Third Edition, Pearson Education
References:
Mike O’Docherty, “Object-Oriented Analysis & Design: Understanding System Development with UML 2.0”, John Wiley & Sons, 2005.

2. James W-Cooper, Addison-Wesley, "Java Design Patterns –A Tutorial", 2000. 4. Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides, "Design patterns: Elements of Reusable object-oriented software", Addison-Wesley, 1995.

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 Code	**CE638**
Course Title	**Foundations of AI**
Credit	**04**
Type of Course	-Core (MTech in CSE) -Professional Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** One Final Evaluation at the End of the Term **50 Marks** Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100 Marks
Prerequisite	Knowledge of Statistical Techniques, Probability Theory, Data Structures and Algorithms, Programming Language such as Python, Matlab.
Course Objectives	The main objective of the course is to introduce concepts of Artificial Intelligence. The general objectives are to learn about computer systems that exhibit intelligent behaviour, design intelligent agents, identify AI problems and solve the problems, design knowledge representation and expert systems, design neural networks for solving problems, identify different machine learning paradigms and identify their practical applications.

Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create		
	CO Title	**Level**	**Descriptor**
	CO1: Student will be able to understand the concepts and basics of AI	L1, L2	Remember, Learn, Understand
	CO2: Student will be able to apply the algorithms for Problem Solving and Knowledge Representation	L3, L4	Apply, Analyse
	CO3: Student will be able to analyze & apply the concepts of Machine Learning for structured and unstructured data	L4, L5	Analyse, Evaluate
	CO4: Student will be able to evaluate the AI based system and propose solutions using various AI models for multi-disciplinary application requirements	L5, L6	Evaluate, Create

Syllabus Description

Basics & Preliminaries	Details	Books & References	Duration	COs
Unit-1	**Introduction:** Artificial Intelligence (AI), AI Perspectives: acting and thinking humanly, acting and thinking rationally, History of AI, Foundations of AI, Applications of AI	T1, R1	8	CO1
Unit-2	**Intelligent Agents:** Introduction of agents, Structure of Intelligent agent, Properties of Intelligent Agents, Configuration of Agents, PEAS description of Agents, Types of Agents: Simple Reflexive, Model Based, Goal Based, Utility Based, Environment Types: Deterministic, Stochastic, Static, Dynamic, Observable, Semi-observable, Single Agent, Multi Agent	T1,R1	8	CO1

Unit-3	**Problem Solving by Searching:** Definition, Problem as a state space search, Problem formulation, Well-defined problems, Solving Problems by Searching, Search Strategies, Performance evaluation of search techniques, Uninformed Search: Depth First Search, Breadth First Search, Depth Limited Search, Iterative Deepening Search, Bidirectional Search, Informed Search: Greedy Best first search, A* search, Hill Climbing, Simulated Annealing, Game playing, Adversarial search techniques, Mini-max Search, Alpha-Beta Pruning, Constraint Satisfaction Problems	T1,R2	8	CO2
Unit-4	**Knowledge Representation:** Definition and importance of Knowledge, Issues in Knowledge Representation, Knowledge Representation Systems, Properties of Knowledge Representation Systems. Types of Knowledge Representation Systems: Semantic Nets, Frames, Conceptual Dependencies, Scripts, Rule Based Systems, Propositional Logic, Predicate Logic Propositional Logic(PL): Syntax, Semantics, Formal logic-connectives, truth tables, tautology, validity, well-formed-formula, Inference using Resolution, Backward-Chaining and Forward Chaining, Predicate Logic: FOPL, Syntax, Semantics, Quantification, Inference with FOPL: By converting into PL (Existential and universal instantiation), Unification and lifting, Inference using resolution, Handling Uncertain Knowledge, Radom Variables, Prior and Posterior Probability, Inference using Full Joint Distribution, Bayes' Rule and its use, Bayesian Networks, Reasoning in Belief Network, Fuzzy Logic	T2, R2, R3	8	CO2
Unit-5	**Machine Learning:** Introduction to Machine Learning, Concepts of Learning, Supervised, Unsupervised and Reinforcement Learning, Statistical-based Learning: Naive Bayes Model	T2,R1,R2	16	CO3
Text Books (MUST Know)	Stuart Russell & Peter Norvig, Artificial Intelligence: A Modern Approach, Prentice-Hall, Third Edition (2009) Micheal Negnivitsky, Artificial Intelligence: A Guide to Intelligent Systems, Addison-Wesley, 3nd Edition, 2011			

Reference Books (SHOULD Know)	E. Rich and K. Knight, Artificial Intelligence, 2nd ed., McGraw-Hill, New York, 1991. M. Ginsberg, Essentials of Artificial Intelligence, Morgan Kaufmann, San Mateo, Ca., 1993. D. Poole and A. Mackworth, Artificial Intelligence: Foundations of Computational Agents, Cambridge University Press, Cambridge, UK, 2010			
Laboratory Assignments/ Demonstrations				
Lab 1	Design and Implement Uninformed Search like DFS, BFS, Greedy Best First, A*, Game Search Like Min Max Search	UNIT III	02 hours	CO1,CO4
Lab 2	Design and Implement constraint satisfaction problems like water jug, n-queen problem, crypto-arithmatic problem.	UNIT III	02 hours	CO1,CO4
Lab 3	Write programs for illustrating the concepts knowledge representation systems like rule based (If -then Else format) and predicate logic (using predicates)	UNIT IV	02 hours	C02,CO4
Lab 4	Write programs for illustrating the concepts knowledge representation systems like frames (using concepts of class) and semantic nets (using concepts of graph	UNIT IV	02 hours	CO2,CO4
Lab 5	Implementing Naive Bayes algorithm	UNIT V	02 hours	CO3,CO4
Lab 6	Implementing Neural Networks for realization of AND, OR gates	UNIT V	02 hours	CO3,CO4
Lab 7	Mini-project. Implementation and Demonstration. Report Submission is essential	UNIT I - V	04 hours	CO4

Subject Code	**CE639**
Subject Title	**Practical Machine Learning**
Credit	**04**
Type of Subject	-Core (MTech in CSE) -Professional Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.

Evaluation Pattern	Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** One Final Evaluation at the End of the Term **50 Marks** Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**				
Total Marks	100 Marks				
Prerequisite	Knowledge of Statistical techniques, Linear algebra and computer programming knowledge is required.				
Dept	CSE				
Course Objectives	To provide the knowledge of Python programming language as it applies to data analytics. Skills will be developed for Data Analysis with Python and develop product in python. Student will learn various ML techniques including Supervised, unsupervised classification and regression analysis, Artificial Neural Networks, etc. Student will learn Python Programming for implementing these algorithms on standard datasets				
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create				

	CO Title	Level	Descriptor
	CO 1 - Students will be able to understand ML paradigms and various Supervised, unsupervised classification and regression analysis methods. (PO1,PO2, PO3, PSO2)	L1, L2	Remember, Learn, Understand
	CO2: Students will be able to understand various ML algorithms like and analyse their applications in real world (PO1,PO2, PO3, PSO2)	L2	Remember, Learn, Understand
	CO3: Students will be able to understand advanced ML algorithms and techniques etc. (PO1,PO2, PO3, PSO2)	L3	Remembering, Understanding, Analysing
	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)	L4	Applying, Analysing

Syllabus Description

Basics & Preliminaries	Details	Books & References	Duration	COs
Unit-1	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,	Textbooks - 1,2	12 Hrs	CO1

	Supervised, unsupervised classification and regression analysis			
Unit-2	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	Textbooks - 2,3	12 Hrs	CO2
Unit-3	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.	Textbooks - 2,3,4	12 Hrs	CO2
Unit-4	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	Textbooks - 4-5, / References - 1-4	12 Hrs	CO3
	LAB/ Assignments/Student Presentations [2T/P per week]	Textbooks - 4-5, / References - 1-4	02 Hrs/week	CO4

Text Books (MUST Know)	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 (SHOULD Know)	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.

Laboratory Assignments/ Demonstrations

1	Study and implement algorithms for data pre-processing and data cleaning	Unit -1	02 hours	CO1, CO3, & CO4

2	Study and implement algorithms for data feature selection reduction.	Unit -1	02 hours	CO1, CO3, & CO4
3	Study and Implement Linear Regression Algorithm for any standard dataset	Unit -2	02 hours	CO2, CO3, & CO4
4	Study and Implement unsupervised clustering Algorithms for any standard dataset	Unit -3	02 hours	CO1, CO3, & CO4
5	Study and Implement KNN for any standard dataset	Unit -3	04 hours	CO1, & CO4
6	Study and Implement ANN for any standard dataset	Unit -3	02 hours	CO2, & CO3
7	Study and Implement PCA for any standard dataset	Unit -3	02 hours	CO3, & CO4
8	Case Study: Use of ML along with Fuzzy Logic/ GA/PSO/ACO to solve real world Problem	Unit -4	04 hours	CO2, & CO3
9	Mini assignment: Apply ML to solve any real world problem	Unit -4	04 hours	CO2, & CO4
10	ML Practice Test – 1 Quiz	Unit - 1,2,3,4	02 hours	CO1,CO2, CO3, & CO4

Course Code	**CE634**
Course Title	**Natural Language Processing**
Credit	**04**
Type of Course	-Core (MTech in CSE) -Professional Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	03 – monthly test + 01 Final Evaluation
Total Marks	100
Prerequisite	Programming, Data Structures, Algorithms
Dept	CSE
Course Objectives	Understanding of basic issues, concepts, principles and mechanisms of Natural Language Processing. Build knowledge in the following areas of theory, programming, application development in NLP, Machine Learning in NLP. Develop, test and validate NLP applications which use machine learning.

Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create		
	CO Title	**Level**	**Descriptor**
	CO1: Students are able to understand the basic concepts of NLP	L1, L2	Remember, Learn, Understand
	CO2: Students are able to process raw text, write structured programs, algorithms, categorizing and tagging words using Automatic and N-Gram Taggers	L3, L4	Apply, Analyse
	CO3: Use supervised and unsupervised learning, Classify text using Decision Trees, Extract information from text	L4, L5	Analyse, Evaluate
	CO4: Analyze Sentence structure, understand and apply grammar development.	L5, L6	Evaluate, Create
	CO5: Analyze meaning of sentences, Natural Language understanding, managing linguistic data, use deep learning for NLP		

Syllabus Description

Basics & Preliminaries	Details	Books & References	Duration	COs
Unit-1	Introduction, Language Processing with Python, Accessing Text Corpora, Conditional Frequency Distribution, Lexical Resources	Text 1, Chap1, 2	3hr	CO1
Unit-2	Processing Raw Text, Accessing Text from Web and Disk, Strings, Regular Expressions, Segmentation, Formatting	Text1, Chap3	4hr	CO1, CO2
Unit-3	Writing Structured Program, Structured Programming, Python Basics, Algorithm Design	Text 1,Chap 4	4hr	CO2
Unit-4	Categorizing and Tagging Words, Tagger, Tagged Corpora, Automatic Tagging, N-Gram Tagging, Transformation based Tagging	Text 1, Chap5	4hr	CO2

Unit-5	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	Text 1, Chap6, 7	6hr	CO3
Unit-6	Analyzing Sentence Structure, Context Free Grammar, Parsing, Dependency, Grammar development.	Text1, Chap 8	4hr	CO3, CO4
Unit -7	Building Feature based Grammar, Grammatical Features, Processing Feature Structures, Extending Feature based Grammar	Text 1, Chap 9	4hr	CO4
Unit -8	Analyzing the Meaning of Sentences, Natural Language Understanding, Propositional Logic, First Order Logic, English Semantics Discourse Semantics	Text 1, Chap 10	6hr	CO4, CO5
Unit -9	Managing Lingusitic Data, Corpus Structure, Working with XML, Working with Toolbox, OLAC	Text 1, Chap 11	6hr	CO5
Unit-10	Unit – X Deep Learning, Transformers, LSTM for NLP	Ref 2	8hr	CO5
Text Books (MUST Know)	S.Bird, E Klein and E Loper, "Natural Language Processing with Python", O'Reilly, 2009.			
Reference Books (SHOULD Know)	D. Jurafsky and JH Martin, "Speech and Language Processing: An Introduction to NLP", Updated, Pearson, 2020. Speech and Language Processing (stanford.edu)			

Laboratory Assignments/ Demonstrations

Lab No	Lab Experiment	Unit	Hours
1	NLTK , Installation and Commands in NLTK	Unit 1	2
2	Python Programming for NLP	Unit 3	2
3	Corpora, Installing and Checking Various Text Corpora	Unit 1, 3	2
4	Processing Raw text, Using NLTK, using Regular expression	Unit 2	2
5	Tagging words, Tagging, N-gram tagging	Unit 4	2
6	Classifying Text, Using classifiers to classify text	Unit 5	2

7	Extracting Information from Text, Chunking, Recursion	Unit 5	2
8	Analysing Sentence Structure, Context Free Grammar, Parsing	Unit 7	2
9	Analysing Meaning of Sentences, Propositional and First Order Logic	Unit 8	2
10	Creating Corpora, Working with XML	Unit 9	2

Course Code	**AM 607**
Course Title	**Mathematics for Engineers**
Credit	**04**
TeachingScheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	03 monthly tests + 01 final evaluation + assignments for internal assessment
Total Marks	100
Prerequisite	NIL
Course Instructor	Faculty from Math Dept
Course offered from Mathematics Department, DIAT	

Syllabus:

Elements of Probability and Statistics: Basic concepts of Probability, Discrete Probability Distributions (Binomial, Poisson etc.),Continuous Probability Distributions (Normal, Exponential, etc.,).

Components of Operations Research:

Introduction to Operations Research, Linear programming (Simplex Method, Revised Simplex Method, Dual simplex, Duality theory),Transportation Models.

Linear Algebra:

General (real) vector spaces, Subspaces, Linear Independence of Vectors, Basis and Dimension, Linear Transformations, Span, Norms,Orthogonal basis and Gram-Schmidt Orthogonalization.

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.

Transform Techniques :

Overview of Laplace transforms, Fourier Transforms, Z transform.

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

Text/References:

Advanced Engineering Mathematics, 11th Ed, 2010, Erwin Kreyszig, Wiley Eastern.
Linear Algebra and its Applications, 4th Ed., 2008, Gilbert Strang, Academic Press.
Numerical Methods for Scientists and Engineers, Joe D. Hoffman, Marcel Dekker Inc.
Numerical Methods for Engineers, Sixth Edition, Steven Chapra and Raymond Canale, McGraw-Hill Education

Elements of Numerical Analysis, 2nd Edition, Radhey S. Gupta**,** Cambridge University Press
Numerical Solutions of Partial Differential Equations: An Introduction, 2nd Ed., 2005, K. W. Morton, D. F. Mayers, CambridgeUniversity Press.
Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.
Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
Differential Equations and Dynamical Systems, Texts in Applied Mathematics, L. Perko, 3rd Ed., Vol. 7, 2006, Springer Verlag,New York.
.S. Gupta.. Calculus of Variation, Prentice Hall of India Pvt. Ltd.

Course Code	**PGC-601**
Course Title	**IPR and Research Methodology**
Credit	**02**
TeachingScheme	Lectures: 02 hours/week
Evaluation Pattern	03 monthly tests + 01 final evaluation + assignments for internal assessment
Total Marks	
Prerequisite	
Course Instructor	**Institute-level conduct**

Syllabus Contents:

Unit 1: 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 2: Effective literature studies approaches, analysis
Plagiarism, Research ethics,

Unit 3: Effective technical writing, how to write report, Paper
Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Unit 4: 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 5: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

Unit 6: New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

References:

Stuart Melville and Wayne Goddard, “Research methodology: an introduction for science & engineering students’”
Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for
Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd,2007.
Mayall, “Industrial Design”, McGraw Hill, 1992.
Niebel, “Product Design”, McGraw Hill, 1974.

Asimov, “Introduction to Design”, Prentice Hall, 1962. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “ Intellectual Property in New Technological Age”, 2016. . T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008

Course Code	**CE631**		
Course Title	**Deep Learning**		
Credit	**04**		
Type of Course	-Core (MTech in CSE) -Professional Open Elective for All Engineering and Science disciplines		
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.		
Evaluation Pattern	03 – monthly test + 01 Final Evaluation		
Total Marks	100		
Prerequisite	Knowledge of Statistical Techniques, Probability Theory, Data Structures and Algorithms, Programming Language such as Python, Matlab.		
Dept	CSE		
Course Objectives	To understand concepts of Deep Learning and Basics of Machine Learning. To understand how to train Deep Models and Convolutional Networks. To understanding and analyze the related study and refer different latest research views in Latest trend and techniques.		
Course Outcomes	Bloom’s Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create		
	CO Title	**Level**	**Descriptor**
	CO1 Remembering the basics of Machine Learning and Deep learning	Level 1 & 2	Remembering, Understanding
	CO2 Understanding the different learning algorithms and techniques in machine Learning	Level 2	Understanding
	CO3 Applying different convolution operation, pooling, Functions and sequence modelling	Level 3	Applying
	CO4 Analyze Various other Deep Learning architectures like RNN, Autoencoders and GANSs	Level 4	Analyzing

	CO5 Analyzing and gain knowledge about Deep Learning Applications	Level 4	Analyzing

Syllabus Description

Basics & Preliminaries	Details	Books & References	Duration	COs
Unit-1	Introduction : Overview of machine learning, linear classifiers, loss functions Optimization : Stochastic gradient descent and contemporary variants, backpropagation	T1, R1	5hr	CO1& CO2
Unit-2	Feedforward networks and training : Activation functions, initialization, regularization, batch normalization, model selection, ensembles.	T1, R1	9hr	
Unit-3	Convolutional neural networks : Fundamentals, architectures, pooling, Visualization, Image Classification and Object Detection using CNN	T1, R4	16hr	CO3
Unit-4	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	T1, R4	10hr	CO4
Unit-5	Deep generative models : Auto-encoders, generative adversarial networks	T1, R4	5hr	CO4
Text Books (MUST Know)	Ian Goodfellow, Y. Bengio, A. Courville, Deep Learning, MIT Press, 2016. http://www. deeplearningbook.org.			
Reference Books (SHOULD Know)	K. P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012. C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006. A National Initiative on AI Skilling and Research (leadingindia.ai) NPTEL Course Lecture Material: Deep Learning Part-1 By Dr. Mitesh Kapra, IIT Chennai.			

Laboratory Assignments/ Demonstrations

Lab No	**Lab Experiment**	**Unit**	Hours	CO’s
1	Implementation of Linear Classifier using ML	Unit 1	2	CO1 & 2
2	Implementation of Activation Functions and analyze the significance of Weight and Bias for ML Model	Unit 2	2	CO1 & 2

3	Implementation of Perceptron Model for Binary Logic.	Unit 2	2	CO1 & 2
4	Implementation of XOR using Multi Layer Perceptron	Unit 2	2	CO1 & 2
5	Implementation of Convolutional Neural Networks	Unit 3	2	CO3
6	Object Detection using CNNs	Unit 3	2	CO3
7	Image Classification Using CNNs	Unit 3	2	CO3
8	Analyzing various CNN Architectures	Unit 3	2	CO3
9	Implementing RNNs and LSTM	Unit 4	2	CO4
10	Analyzing CNNs and RNNs for DeepLearning Applications	Unit 5	2	CO4

Subject Code	**CE632**
Subject Title	**Computer Vision**
Credit	**04**
Type of Subject	-Core (MTech in CSE) -Professional Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** One Final Evaluation at the End of the Term **50 Marks** Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100 Marks
Prerequisite	Statistical techniques, Linear algebra and computer programming knowledge is required.
Dept	CSE
Course Objectives	To introduce students the fundamentals of image formation; To introduce students the major ideas, methods, and techniques of computer vision and pattern recognition; To develop an appreciation for various issues in the design of computer vision and object recognition systems; and To provide the student with programming experience from implementing computer vision and object recognition applications.
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create

	CO Title	**Level**	**Descriptor**
	CO1: Students will be able to understand and apply image processing techniques including filtering operations, thresholding techniques, edge detection techniques etc. (PO1, PO2, PO3, PSO2)	L1, L2	Remember, Understand

	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)	L3	Remember, Understand Analyse
	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)	L3	Remember, Understand Analyse
	CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in computer vision related domain. (PO1, PO2, PO3, PSO2)	L4	Apply, Analyse

Syllabus Description

Basics & Preliminaries	Details	Books & References	Duration	COs
Unit-1	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	Textbooks - 1	12L	CO1
Unit-2	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 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	Textbooks - 2	12L	CO2
Unit-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	Textbooks - 2,3	12L	CO2
Unit-4	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	Textbooks/ References -4-8	12L	CO3
	LAB/ Assignments/Student Presentations [2T/P per week]		02L/Week	CO4

Text Books	E. R. Davies, "Computer & Machine Vision", Fourth Edition, Academic Press, 2012. R. Szeliski, "Computer Vision: Algorithms and Applications", Springer 2011. Simon J. D. Prince, "Computer Vision: Models, Learning, and Inference", Cambridge University Press, 2012. Mark Nixon and Alberto S. Aquado, "Feature Extraction & Image Processing for Computer Vision", Third Edition, Academic Press, 2012.			
Reference Books	D. L. Baggio et al., "Mastering OpenCV with Practical Computer Vision Projects", Packt Publishing, 2012. Jan Erik Solem, "Programming Computer Vision with Python: Tools and algorithms for analyzing images", O'Reilly Media, 2012. Sunita Vikrant Dhavale, "Advanced Image-based Spam Detection and Filtering Techniques", IGI Global, 2017 Research paper for study (if any) - White papers on multimedia from IEEE/ACM/Elsevier/Spinger/ NVidia sources.			
Laboratory Assignments/ Demonstrations				
1	Introduction to Digital Image Processing using python	Unit -1	02 hours	CO1, CO2,CO3, & CO4
2	Study and Implement Image Transformation Techniques	Unit -1	02 hours	CO1, CO3, & CO4
3	Study and Implement Image Transformation Techniques	Unit -1	02 hours	CO2, CO3, & CO4
4	Study and Implement Edge Detection Techniques	Unit -1	02 hours	CO1, CO3, & CO4
5	Study and Implement Image Thresholding Transform	Unit -1	04 hours	CO1, & CO4
6	Study and Implement Morphological Operations	Unit -2	02 hours	CO2, & CO3
7	Study and Implement Harris Corner Point Detection	Unit -2	02 hours	CO3, & CO4
8	Study and Implement SIFT	Unit -3	04 hours	CO2, & CO3
9	Mini assignment: Apply CV techniques to solve any real world problem/ Presentations	Unit -4	04 hours	CO2, & CO4
10	CV Practice Test -1Quiz/ Presentations	Unit -4	02 hours	CO1,CO2, CO3, & CO4

SEMESTER II ELECTIVE COURSES

Subject Code	**CE695A**
Subject Title	**Cyber Physical Systems**
Credit	**04**
Type of Sub	- Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** One Final Evaluation at the End of the Term **50 Marks** Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100 Marks
Prerequisite	None. First 10 hours will be devoted for Prerequisite learnings related to basics of Databases (04 hours), Computer Networks (02 Hours), Operating System (02 Hours), Trends in evolutions of Compute-Devices (02 Hours)
Dept	CSE
About the Course	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 Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create				
	CO Title	**Level**	**Descriptor**	**Out come**	
	CO1: Students will be able to understand the scope of applications of CPS.	L1, L2	Remember, Learn, Understand	20%	
	CO2: Students will be able to analyse the various components of CPS	L3, L4	Apply, Analyse	20%	
	CO3: Students will apply mechanisms to enable autonomous and self-organising techniques	L4, L5	Analyse, Evaluate	20%	
	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)	L5, L6	Evaluate, Create	40%	
Summary of the Course Out Come	At the end of the course, a student will understand the concepts of CPS. Develop skills to relate a CPS as a feedback system along with its designing, modelling and implementation challenges. Evaluate the requirements to address emerging areas of digitization, AIML, and Secure environments.				
Syllabus Description					
Basics & Preliminaries	Role of Basic and Advanced Data Structures in Data Models, Types of Data Models, Basic Dictionary Data Types; Algorithms and basics of analysis, OS & Algorithms in Parallel Environments. Protocols of Computer Networks preliminaries, Concerns for Data Security and Privacy	Cormen et al, Horowitz Sahani, Bipin Desai, Korth et al.	10 Hours		CO1, PO1

		Kurose Ross		
Unit-1	CPS: Introduction Main Concepts, Challenges; Background role of Computer Networks, Data, Algorithms	Text Book-1, Ch-1	08 Hours	CO1, CO2, PO1
Unit-2	Self-organising Systems, Self-organisation in Natural Systems Inspiring Self-organising Software,	Text Book-1, Ch-2, 3	04 Hours	CO1, PO1
Unit-3	Agents and Multi-Agent Systems Computing trends, Data device proliferation, Confluence of trends	Text Book-1, Ch-4	06 Hours	CO1 CO2, PO1
Unit-4	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	Text Book-1, Ch-4, 5	06 Hours	CO3, PO2
Unit-5	Engineering Self-organising Systems, Middleware Infrastructures for Self-organising Pervasive Computing Systems	Text Book-1, Ch 5,6,7,8	06 Hours	CO3, PO2
Unit-6	CPS design Standards, Time Models, CPS Special Interest Groups and Mitre Commendations in Design and developments	Weblink References	06 Hours	C04, PO4
Unit-7	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.	Text book-1, Ch-8,9	06 Hours	CO1, CO4, PO1, PO3
Text Books (MUST Know)	Text Books 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		Must Know	
Reference Books (SHOULD Know)	Reference Book-1 "Principles of Cyber-Physical Systems" - Rajeev Alur, MIT Press, 2015		Should Know	

	Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006 Kurose and Ross, Top Down Approach of Computer Networks, Prentice Hall, 8th Edition 2021.			
Consortium, e-books and Web Link references (SHOULD/ Could Know)	https://iveybusinessjournal.com/publication/why-big-data-is-the-new-competitive-advantage/https://www.cdsaonline.org/cps-standard/ https://pages.nist.gov/cpspwg/ International Association for Automation Research Papers shared by the subject incharge		Should and May know	
Laboratory Assignments/ Demonstrations				
LAB Assignments	*Each student will work on unique case study. Will require approval of the same at the beginning. Report submission is essential for each Lab Assignment.			
1	Describe the Use Case*. Model the case study. Abstract.	Unit-1	02 hours	CO1
2	Modelling Tools exploration and implementation of the subsystems/ systems of the case study.	Unit-2	02 hours	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.	Unit 6	02 hours	CO4

	Specify the security concern and mitigation technique. Generate the incidence response reports.			
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

Subject Code	**CE-664A**
Subject Title	**Network and Cloud Security**
Credit	**04**
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	03 monthly tests + 01 final evaluation + assignments for internal assessment
Total Marks	100
Prerequisite	Basic computer networking, operating systems and computer programming knowledge is required.

Objective:

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 Outcomes:

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)				
Syllabus:				
Syllabus Details		**Text Book**	**Hours**	**Outcome**
Unit 1	Introduction, OSI security Architecture, Security Principles, Attacks and Threats, Model of Network Security Security at Application Layer: Email Architecture, PGP, S/MIME	Text book 1 Chap 1, & 8	6	CO1
Unit 2	Security at Transport Layer: SSL Architecture, TLS, SET, HTTPS protocols Security at Network Layer, IPSec, VPN, ISKMP Firewall: Types of Firewalls, Firewall configuration, DMZ, UTMs	Text Book1, Chap 6 & 9**, 12**	12	CO1
Unit 3	Intrusion Detection and Intrusion Prevention Systems, Honeypots, Distributed IDS, Password Management Authentication: kerberos, X509, Authentication, PKI	Text Book 1 Chap 11 & 4	7	CO2
Unit 4	Wireless Security: Wireless LAN, 802.11 Standards, Security of WLAN Cloud Security: Cloud Computing, Security Issues and Challenges, Applications	Text Book 1 Chap 5, 7	9	CO2
Unit 5	DDoS : Direct, Reflector and Amplifier Attacks, TCP Syn Flooding, Countermeasures, Digital Attack Maps Malicious Software: Viruses, Worms, Ransomware etc, Anti-virus Architecture, Generation of Anti-Virus, Types of Viruses in network and cloud Network and cloud Reconnaissance, Traceroute, Port Scanning, ICMP Scanning, Sniffing, Probing Routers in cloud	Text Book 1 Chap 10 Text Book 2,3	9	CO3
Unit 6	Game Theory applications in Network Security Miscellaneous topics and current developments, Dark Web Network Security Observatory: Monitoring Networks	Research Papers & Ref 1	11	CO3
Text Book: 1. William Stallings, “Network Security Essentials”, 6th Edition, Pearson Education, 2019. 2. B. Menezes, “Network Security and Cryptography”, Cengage, 2013. 3. W. Du, “Computer and Internet Security: A Hands On Approach”, 3rd Edition, 2022.				
Reference Books: 1. T.Alpcan and T. Basar, “Network Security: A Decision and Game-Theoritic Apparoach”, Cambridge University Press, 2010. 2. Bragg et al. “Network Security: The complete Reference”, McGraw Hill, 2004 3. Seedlabs: https://seedsecuritylabs.org/ (last accessed on 12th June 2022).				
Lab Assignments				

Sl No	Lab Experiment	Unit	Hours	Outcome
1	Packet Sniffing and Spoofing Lab	1	2	CO1, CO4
2	TCP attacks Lab	2	2	CO1, CO4
3	Firewall Exploration Lab	2	2	CO1, CO4
4	VPN Lab	2	2	CO1, CO4
5	Wireshark Lab	5	2	CO3, CO4
6	Snort: Intrusion Detection Lab	3	2	CO2, CO4
7	CyberCiege Lab	1	2	CO1, CO4
8	OpenSSL Exploration Lab	2	2	CO1, CO4
9	Digital Attack Maps DOS lab	5	2	CO3, CO4
10	Cloud Computing Lab	4	2	CO2, CO4

Subject Code	**CE630**
Subject Title	**Virtual Reality**
Credit	**04**
Type of Subject	-Core (MTech in CSE) -Professional Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	. Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** . One Final Evaluation at the End of the Term **50 Marks** . Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**
Total Marks	100 Marks
Prerequisite	Basic Operating systems and Computer Programming, Computer Graphics knowledge is required.
Dept	CSE
Course Objectives	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
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create

	CO Title	Level	Descriptor
	CO1: Students will be able to understand and apply Virtual Reality Concepts along with various applications. (PO1, PO3, PSO1)	L2	Remember, Understand
	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)	L3,	Remember, Understand Analyse
	CO3 - Students will be able to understand the importance of implementation of Virtual Reality Systems, Applications with Benefits and limitations(PO1, PO3, PSO1)	L2	Remember, Understand
	CO4: Students will be capable of applying their knowledge and skills to solve engineering problems in Virtual Reality. (PO1, PO2, PO3, PSO1, PSO2)	L4	Apply, Analyse

Syllabus Description

Basics & Preliminaries	Details	Books & References	Duration	COs
Unit-1	Introduction, Definition, Applications	Lavalle, Chap1	3L	1,2
Unit-2	Bird's Eye View, Hardware, Software, Human Physiology and Perception	Lavalle, Chap2	3L	1,2
Unit-3	Geometry of Virtual Worlds, Geometric models, Viewing Transformations, Chaining Transformations	Lavalle, Chap 3	4L	1,2
Unit-4	Light and Optics, Lenses, optical aberrations, Human Eye, Cameras, displays	Lavalle, Chap 4	4L	1,2

Unit-5	Physiology of Human Vision: Cornea, Photoreceptors, Eye Movements, Implications for VR	Lavalle, Chap 5	3L	1,2
Unit-6	Visual Perception: Perception of Depth, Perception of Motion, Perception of Color, Combining sources of information	Lavalle, Chap 6	4L	1,2,3
Unit-7	Visual Rendering: Ray tracing and Shading models, Rasterization, Correcting optical distortions, Improving latency and frame rates, Immersive photos and videos	Lavalle, Chap 7	4L	1,2
Unit-8	Motion in Real and Virtual Worlds: Velocities and accelerations, Vestibular system, Physics in virtual world, Mismatched motion and vection	Lavalle, Chap 8	4L	1.2
Unit-9	Tracking: Tracking in 2D, Tracking in 3D, Tracking position and orientation, Tracking attached bodies, 3D scanning of environment	Lavalle, Chap 9	4L	1,2
Unit-10	Interaction: Motor programming and remapping, Locomotion and manipulation, social interaction and other interaction mechanisms	Lavalle, Chap 10	3L	1,2,3
Unit-11	Audio: Physics and sound, physiology of human hearing, Auditory perception, Auditory hearing	Lavalle, Chap 11	3L	1,2
Unit-12	Evaluation of VR Systems and Experiences: Perceptual training, recommendation for developers, Comfort and VR Sickness, Experiments on Human Subjects	Lavalle, Chap 12	6L	4
Unit-13	Frontiers: Touch and Proprioception, Smell and taste, Robotic interfaces and Brain-machine interfaces	Lavalle, Chap 13	3L	2
Text Books (MUST Know)	1. Steven Lavalle, "Virtual Reality", Cambridge Univerisity Press, (lavalle.pl/vr/book.html), 2020			
Reference Books (SHOULD Know)	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.			
Laboratory Assignments/ Demonstrations				

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 device	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

Subject Code	**CE665A**
Subject Title	**Security Standards & Penetration Testing**
Credit	**04**
Type of Subject	-Core (MTech in CSE) -Professional Open Elective for All Engineering and Science disciplines
Teaching Scheme	Lectures: 03 hours/week Tutorial/Practical: 02 hours/week Total Contact hours 05 per week.
Evaluation Pattern	. Continuous Evaluations: Three Monthly Test (10 Marks Each) **30 Marks** . One Final Evaluation at the End of the Term **50 Marks** . Lab Assignments/Mini-Project and Term Work Evaluations: **20 Marks**

Total Marks	100 Marks
Prerequisite	Basic computer networking, operating systems and computer programming knowledge is required.
Dept	CSE
Course Objectives	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
Course Outcomes	Bloom's Taxonomy: Level-1 Remember; Level-2 Understand; Level-3 Apply; Level-4 Analyze Level-5 Evaluate; Level-6 Create

	CO Title	Level	Descriptor
	CO1: 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)	L1, L2	Remember, Understand
	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)	L3	Remember, Understand Analyse
	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)	L3	Remember, Understand Analyse
	CO1, 03: End semester Exam	L4	Apply, Analyse

Syllabus Description

Basics & Preliminaries	**Details**	**Books & References**	**Duration**	**COs**
Unit-1	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	Textbooks - 1,2	12L	CO1

	Tools, Common Criteria for Information Technology Security Evaluation, Information security management systems (ISMS), ISO27000 and other security standards, Management responsibility, Responsibilities of Chief Information Security Officer (CISO)			
Unit-2	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.	Textbooks - 2,3	12L	CO3
Unit-3	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	Textbooks - 2,3,4,5,6 References -1-7	12L	CO2
Unit-4	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	Textbooks - 4-6, / References -1-7	12L	CO2
	LAB/ Assignments/Student Presentations [2T/P per week		02L/ Week	CO4

Text Books (MUST Know)	Michael E Whitman, Herbert J Mattord, "Principles of Information Security", Course Technology, 3rd Edition, 2008. Dhavale, S. V. (2019). Constructing an Ethical Hacking Knowledge Base for Threat Awareness and Prevention (pp. 1-305). Hershey, PA: IGI Global. Stuart McClure, Joel Scambray, George Kurtz, "Hacking Exposed:n/w sec secrets and solutions", Mcgraw Hill, 2012			
Reference Books (SHOULD Know)	. Various Security Standards - ISO 27000 series published by ISO. . Department of Defense Standard, Department of Defense, "Trusted Computer System Evaluation Criteria", Orange Book. . Dieter Gollmann, "Computer Security", John Wiley and Sons, Inc., 3rd edition, 2011 . David Kennedy, Jim O'Gorman, Devon Kearns, and MatiAharoni, "Metasploitpentest guide",No starch Press, san Francisco, 2011 . Bastian ballman, "Understanding n/w hacks:attack and defense with python", Springer,2012 . 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 . Krutz, R. L. & Vines, R. D., "The CISSP and CAP Prep Guide", Platinum Edition, New York, Wiley Publishing., 2006. . Nina Godbole, "Information Systems Security: Security Management, Metrics, Frameworks and Best Practices", Wiley India Pvt Ltd, 2012. . William Stallings and Lawrie Brown, "Computer Security: Principles and Practice", 2nd edition, Pearson, 2012.			
Laboratory Assignments/ Demonstrations				
1	Study Windows Essential Tools-Part 1	Unit - 1	02 hours	CO1, CO2,CO3, & CO4
2	Study Windows Essential Tools-Part 2	Unit - 1	02 hours	CO1, CO3, & CO4
3	Study Sysinternals utilities to manage, diagnose, troubleshoot, and monitor a Microsoft Windows environment	Unit - 2	02 hours	CO2, CO3, & CO4
4	Study passive information gathering tools.	Unit - 3	02 hours	CO1, CO3, & CO4
5	Write Security Policy Document	Unit - 3	04 hours	CO1, & CO4
6	Case study: LDRA and Parasoft tools	Unit - 3	02 hours	CO2, & CO3
7	Kali Linux Attacks – Part1	Unit - 3	02 hours	CO3, & CO4
8	Kali Linux Attacks – Part2	Unit - 4	04 hours	CO2, & CO3
9	SSPT Practice Test -1Quiz	Unit - 4	02 hours	CO2, & CO4
10	Apply data mining tools for cyber security related data analysis	Unit - 4	04 hours	CO1,CO2, CO3, & CO4

CE633 Pattern RecognitionSyllabus:

Unit I: Basics of Probability, Random Processes and Linear Algebra (recap): Probability: independence of events, conditional and joint probability, Bayes theorem Random Processes: Stationary and non-stationary processes, Expectation, Autocorrelation, Cross-Correlation, spectra.
Unit II : Linear Algebra: Inner product, outer product, inverses, eigen values, eigen vectors,singular values, singular vectors.
Unit III: Bayes Decision Theory : Minimum-error-rate classification. Classifiers, Discriminant functions, Decision surfaces.Normal density and discriminant functions. Discrete features.
Unit IV: Parameter Estimation Methods : Maximum-Likelihood estimation :Gaussian case. Maximum a Posteriori estimation. Bayesian estimation: Gaussian case. Unsupervised learning and clustering - Criterion functions for clustering. Algorithms for clustering: K- Means, Hierarchical and other methods. Cluster validation. Gaussian mixture models, Expectation-Maximization method for parameter estimation. Maximum entropy estimation.Sequential Pattern Recognition. Hidden Markov Models (HMMs). Discrete HMMs. Continuous HMMs. Nonparametric techniques for density estimation.Parzen- window method.K-Nearest Neighbour method.
Unit V: Dimensionality reduction: Principal component analysis - it relationship to eigen analysis. Fisher discriminant analysis - Generalised eigen analysis. Eigen vectors/Singular vectors as dictionaries. Factor Analysis, Total variability space - a dictionary learning methods.Non negative matrix factorisation - a dictionary learning method.
Unit VI: Linear discriminant functions : Gradient descent procedures, Perceptron, Support vector machines - a brief introduction.
Unit VII: Artificial neural networks: Multilayer perceptron - feedforwark neural network.A brief introduction to deep neural networks, convolutional neural networks, recurrent neural networks.
Unit VIII: Non-metric methods for pattern classification : Non-numeric data or nominal data. Decision trees: Classification and Regression Trees (CART).

Text /Reference Books:

1. R.O.Duda, P.E.Hart and D.G.Stork, Pattern Classification, John Wiley, 2001
2. S.Theodoridis and K.Koutroumbas, Pattern Recognition, 4th Ed., Academic Press, 2009
3. C.M.Bishop, Pattern Recognition and Machine Learning, Springer, 2006

CE691 SECURE WIRELESS SENSOR NETWORKS

Background: Wireless Sensor networks (WSN) is an emerging technology and have great potential to be employed in critical situations like battlefields and commercial applications such as building, traffic surveillance, habitat monitoring and smart homes and many more scenarios. One of the major challenges wireless sensor networks face today is security. While the deployment of sensor nodes in an unattended environment makes the networks vulnerable to a variety of potential attacks, the inherent power and memory limitations of sensor nodes makes conventional security solutions unfeasible. The sensing technology combined with processing power and wireless communication makes it profitable for being exploited in great quantity in future. The wireless communication technology also acquires various types of security threats.

Objective**:** To meet End-User, Network-Administrator and Network-Designer perspectives

Prerequisite: Computer Networks Fundamentals, Programming,

Syllabus:

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 Book:

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

Research Paper References:

20. Ian F. Akykildiz, Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci, ―A Survey on Sensor Networks‖, IEEE Communication Magazine, year 2002.
21. Culler, D. E and Hong, W., ―Wireless Sensor Networks‖, Communication of the ACM, Vol. 47, No. 6, June 2004, pp. 30-33.
22. Adrian Perrig, John Stankovic, David Wagner, ―Security in Wireless Sensor Networks‖ Communications of the ACM, Page53-57, 2004
23. Chris Karlof, David Wagner, ―Secure Routing in Wireless Sensor Networks: Attacks and Countermeasures‖, AdHoc Networks (elsevier), Page: 299-302, year 2003
24. 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
25. 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
26. 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
27. 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
28. 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
29. Zia, T.; Zomaya, A., ―Security Issues in Wireless Sensor Networks‖, Systems and Networks Communications (ICSNC) Page(s):40 – 40, year 2006
30. 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
31. 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.
32. 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.
33. 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.
34. Yun Zhou, Yuguang Fang, Yanchao Zhang, Securing Wireless Sensor Networks: A Survey, IEEE Communications Surveys & Tutorials, year 2008
35. Xiuli Ren, Security Methods for Wireless Sensor Networks, Proceedings of the 2006 IEEE International Conference on Mechatronics and Automation , Page: 1925 ,year 2006
36. 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.
37. 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.
38. 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.

<u>Tutorials:</u>

k. Routing techniques: Overview of Proactive and reactive routing protocols, significance of *a hop* in adhoc networks
l. Flooding, Gossiping, Zonal Routing Protocols ZRP, Hybrid Routing, TTL significance with respect to routing protocols
m. Impact of hardware and software on Battery Performances/Utilisation
n. IEEE 802.15.4: A study, Features, Types of Devices FFD (PAN coordinators, Coordinators), RFDs Reduced Function Devices, Network Setup process & parameters in Consideration, Programming Strategies to suit the standards, MAC and PHY structure
o. Demo 1: Controlling DIOs. Demonstrate the usage of DIO using LEDs. Learning how to handle data sampling period.
p. Demo 2. Reading data from a single IoT device. Interpretation of data.
q. Demo 3: Create a broadcast wireless network and capture the traffic generated by the participating nodes.
r. Demo 4. Creating a multi-hop network using MBR routing.
s. Understanding MBR & LBR (MAC Based Routing and LBR Level-Based Routing)
t. Understanding exiting API, Libraries & its association with pre-existing demonstration codes.

<u>CE699 Internet of Things</u>
Syllabus:

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

Text /Reference 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.

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

The Department of Computer Science and Engineering was established in 1987. The Department of Computer Science & Engineering offers M. Tech., M.S (by Research) and Ph.D. programs for DRDO scientists, Tri-services and GATE qualified students. Currently, there are 06 faculty members in the department with PhD Degrees. Currently, the department has 12 PhD research scholars and 36 M.Tech. students.

The thrust areas of the Department are Cyber Security, Ethical Hacking, Information Warfare, Network Centric Warfare, Cryptography, Network Security, Information Security Management Systems, Digital Forensics, Malware Analysis, Multimedia Security, Wireless Security. The faculty are also actively working in the following domains : Computational Intelligence, Machine Learning, Artificial Intelligence, SAR Imaging, Data Mining, Trusted Computing, Secure Software Engineering, Program Analysis, Malware Analysis, High Performance Computing, Soft Computing, Modelling and Simulation, Social Network Analysis etc.

The Department has successfully organized Two Weeks short term training courses on Artificial Intelligence and Machine Learning, Cryptology and Cyber Security for Navy Officers, NTRO (National Technical Research Organization) in May 2022, October 2021 and Oct 2019; NCECE 2016 (National Conference on Electronics and Computer Science – Theme: Defence Applications) Sponsored by BEL and NCSDAQC 2017(National Cyber Security Seminar, Debate and Quiz Contest) during July 2017 sponsored by DRDO.

The Department has also conducted several workshops on Ethical Hacking, Cyber Security, Nine Algorithms, IT and Defence etc. The department had received NVIDIA academic research grant, 2018 for deep learning-based research activities.

The Department of Computer Engineering is associated with the data center activities to facilitate the email, WiFi, internet, web hosting, etc. to the DIAT campus. The establishment of National Knowledge Network facility, Virtual Classroom with Video Conferencing, campus-wide Wi-Fi connectivity, PHMC CCTV facility in DIAT are important initiatives of Computer Science & Engineering Department.
The M. Tech. degree in Computer Science and Engineering had started in the academic year 2009 and the two batches have passed out till June 2012. The Department has started M.Tech. with specialization in Cyber Security since July 2011. The first batch passed out in June 2013.
The Department has very good relations with industry, DRDO labs and other academic institutes, hence has a strong placement record.

Institute Vision

To be a Center of Excellence of international repute for Education, Training and Research in Advanced Technologies with a view to strengthen national security and self reliance.

Institute Mission

To evolve as an Innovative Unique Research University to develop indigenous contemporary Defence related technologies in Navigation Systems, Wireless Sensors, Efficient Propulsion Systems, Weapon Systems for DRDO and Defence Services, provide technological solutions to the Services to optimise combat battlefield effectiveness and above all produce qualified quality manpower which can truly become an instrument for building a strong indigenous technology base in the context of creating a performing Defence Industrial Base in India.

Department Vision

To be a Center of Excellence of International repute to provide high quality education, research and training in the area of Cyber Security (CS) and Artificial Intelligence (AI) to promote innovation and entrepreneurship skills amongst the students with a view to strengthen national security and self-reliance.

Department Mission

M1: To build strong education, teaching and research environment in the field of Cyber Security (CS) and Artificial Intelligence (AI) to meet requirements from defence, specially related to national security.

M2: To strive for continuous learning, innovation, entrepreneurship and quality research culture amongst the student community through effective government, industry & academia collaboration.

M3: To encourage ethics, team work and technological leadership skills amongst students to solve complex engineering problems collaboratively by imparting strong theoretical foundation complemented with extensive practical training.

M4: To develop high quality indigenous technological solutions catering defence and civil needs by carrying out multidisciplinary collaborative research.

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. Computer Science and Engineering with specialization 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.

APPLIED MATHEMATICS

M. Tech in Modelling and Simulation

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.

Department of Applied Mathematics offers a two-year Multidisciplinary M. Tech. (Modelling & Simulation) programme, and also offers a Doctoral Degree programme in the areas of Applied Mathematics. This programme was provisionally accredited by NBA.

The aim of the Department was to provide training in depth knowledge of various modelling and simulation techniques and also mathematical topics to various courses conducted at DIAT. The present faculty strength of the Department is five and one visiting faculty. The Department is also actively engaged in handling the projects from various agencies. Since then the Department members have been actively involved in the research in different fields of applied mathematics such as ballistics, flight dynamics, hydro-dynamics, hydro-ballistics, Numerical Methods and Optimization, Statistics, Probability. Recently the Department has also developed expertise in the advanced Modelling and Simulation techniques like Neural Network, Fuzzy Logic and Genetic Algorithm, Parallel Computing, Cryptography and Machine Learning.

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
- ❖ Finite Element Analysis in Fluid Flow through Porous Media
- ❖ Computational Fluid Dynamics
- ❖ Partial Differential Equations & their Applications
- ❖ Image Processing
- ❖ Numerical Analysis of PDEs
- • Finite Elements Method
- • Boundary Element Method
- • Domain Decomposition Method & Fictitious Domain Method
- ❖ Boundary Layer Theory
- ❖ Numerical Parallel Algorithms and Parallel Computing.
- ❖ Bio-Mechanics
- ❖ Cryptography

Vision of the Department

- ✓ To provide high quality education, research and training in Applied Mathematics and in the Multidisciplinary area: “Modelling and Simulation” for solving the complex problems.

Mission of the Department

- ✓ To build strong teaching and research environment for basic and applied research with thrust to defence related problems.
- ✓ To encourage and help the students community to develop mathematical and statistical models and also exploit available tools for solving real life and defence related problems.
- ✓ To become a premier department in the country in the area of "Modelling and Simulation" and applications of mathematics.
- ✓ To provide high quality education, research and customised training in the area of "Modelling and Simulation" for

DRDO Scientists, Service Officers, DPSU and other civilian community.

Programme Educational Objectives

- ✓ The department of Applied Mathematics is committed to impart knowledge related to Modelling & Simulation and applied mathematical techniques to students and service officers to obtain realistic and reasonable solutions for real world and defence related problems to meet the challenges of current and future requirements of nation.
- ✓ Being an interdisciplinary programme, such knowledge can help to solve the problem holistically and to achieve successful career and professional accomplishment.
- ✓ To inculcate positive attitude, professional ethics, effective communication and interpersonal skills which would facilitate them to succeed in the chosen profession exhibiting creativity and innovation through research and development both as team member and as well as leader.

Programme Outcomes (POs)

- ✓ The department imparts higher education and training in the field of modelling and simulation meeting the defence, industries and academic requirement of the country.
- ✓ Various courses offered under his programme help to develop various mathematical models cutting across the boundaries and to understand simulation techniques.
- ✓ 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.
- ✓ This is a unique capability which helps the students to establish themselves as a successful professional.
- ✓ An ability to function on multidisciplinary teams involving interpersonal skills.
- ✓ 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 in CSE / IT / ECE / ME / AE. OR MSc / MS degree in CS / IT / Mathematics / Physics / Electronics Provided 1) Mathematics is one of the subject at the graduate level and 2) Knowledge in computer programming is desirable

CSE - Computer Science Engineering
IT - Information Technology
AE - Aerospace Engineering
ECE - Electronics & Communication Engineering

ME - Mechanical Engineering

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 assigenemts / 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 stuructures (C / C++) / MATLAB / MATHEMATICA / Simula8 / Maplesim / SPSS / R / Extend Sim. . .etc., All these softwares 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 where as 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 fourthe 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	Advanced Numerical Methods	3	1	4
2.	AM 602	Mathematical Modelling & System Analysis	3	1	4
3.	AM 603	Advanced Optimization Techniques	3	1	4
4.	AM 604	Advanced Statistical Techniques	3	1	4
5.	AM 605	Computer Graphics	3	1	4
6.	AM 606	Mathematical Methods	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 Department(AM)]	3	1	4

4.		Elective II [From Department(AM)]	3	1	4
5.		Elective III	3	1	4
6.		Elective IV	3	1	4
7.	PGC-602	Audit Course	2	0	0
		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/ week

Note: During summer vacation (4 Weeks), Summer Internship / Industirial Tour will be accepted for all students relavant to the dissertation work especially modeling and Simualtion

<u>List of Electives are given Below:</u>

Sl. No.	Course Code	Course
Elective I, II		
	AM 623	Machine Learning
	AM 624	Tensor Analysis and Engineering Applications
	AM 625	Digital Image Processing
	AM 626	Computational Heat and Mass Transfer
	AM 627	Introduction to Non Newtonian Fluids
	AM 628	Computational Number Theory and Cryptography
	AM 629	Calculus of Variations and Integral Equations
	AM 630	Domain Decomposition Methods
	AM 631	Multigrid Methods
	AM 632	Ballistics
	AM 633	Bio-Mechanics

AM 601 Advanced Numerical Methods

Course Code	**AM 601**

Course Name	***Advanced Numerical Methods***
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

CO1: Understand the methods for solving ODE’s PDE’s using various Numerical methods that can help to make decisions for practical problems in industries and apply basic concepts of mathematics to formulate problem which can be solved by an appropriate Numerical method.

CO2: Students are be able to understand the importance of Numerical method that could arise out of various processes and judge an appropriate method that could be used to solve the governing equations of a model.

CO3: Students are be able to analyze and appreciate the variety numerical methods such as FDM and FVM that can be applied to solve a specific model.

CO4: Students are be able to implement, develop and promote research interest in applying numerical methods in problems of Engineering and Technology.

Solution of Ordinary Differential Equations: Taylor series method – Euler and Modified Euler methods – Runge kutta methods– Multistep methods – Milne‟s method – Adams Moulton method.

Boundary Value Problems and Characteristic Value Problems: The shooting method – solution through a set of equations – Derivative boundary conditions – Characteristic value problems – Eigen values of a matrix by Iteration – The power method.

Numerical Solution of Partial Differential Equations- Finite Difference Methods (FDM) : (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 Finite Differences

Finite difference approximations for partial derivatives and finite difference schemes:

Alternate Direction Implicit (ADI) method, Maccormack predictor-corrector method, Lax-Wendroff Method. Dirichlet‘s problem, Neumann problem, mixed boundary value problem. Higher order compact (HOC) scheme.

Basic concepts of finite volume method (FVM):

Gauss-divergence theorem. Four basic rules. General discretization techniques. Source term linearization and boundary conditions. Over relaxation and under relaxation techniques. Location of control volume faces. Staggered grid concept. Application of FVM. Advantage and disadvantage with the FDM.

Text / References:

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.
3. Computational Methods for Partial Differential Equations, 2007, M. K. Jain, S. R. K. Iyengar, New Age International.
4. Applied Numerical Analysis, 7th Ed., 2003, Curtis F. Gerald, Patrick O. Wheatley, Pearson Education.
5. Numerical Methods Using MATLAB, 4th Ed., 2004, John H. Mathews, Kurtis D. Fink, Pearson Education.
6. An Introduction to Computational Fluid Dynamics - The Finite Volume Method, 2nd Ed., 2007, H. K. Versteeg, W. Malalasekera, Pearson Education.

AM 602 Mathematical Modelling and System Analysis

Course Code	**AM 602**
Course Name	***Mathematical Modelling and System Analysis***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Outcomes:

CO1: Students are able to understand the importance of modeling the physical phenomenons 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.

Mathematical Modelling: Introduction to modelling and simulation, Classification of systems into continuous and discrete, Structural characterization of mathematical model and validation techniques.
Modelling Techniques: Dimensional analysis: Concept behind dimensional approach, Buckingham Pi theorem, Models using dimensional approach.
Continuous approach: Models based on physical laws.
Discrete Approach: Models based on discrete approach. Prey - Predator models.
Combat Modelling: Modelling the Lanchester laws with System Dynamics.
System Analysis: The state of a system, mathematical models of continuous linear lumped parameter, time invariant systems, Discrete time systems, Linear approximation of non-linear systems, Topological models of system, Block diagram representation, Signal flow graph, and Mason‘s rule. A generalized approach to modelling. Principles of conservation and continuity and Applications. Basics of simulator technology.

Text Books / References

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.
4. Introduction to System Dynamics, 1967, J.L. Shearer, A.T. Murphy, H.H. Richardson, Addison& Wesley.
5. Introduction to System Analysis, 1985, T.H. Glisson, McGraw Hill.

AM – 603 Advanced Optimization Techniques

Course Code	**AM 603**
Course Name	***Advanced Optimization Techniques***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Outcomes:

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: Students are be able to 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: Students are be able to analyze and appreciate the variety of performance measures for various optimization problems such as Sensitivity analysis, Risk analysis and Portfolio Management, etc.

CO4: Students are be able to 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.

Linear programming: Simplex method, Two-phase method, Big-M method, duality, Integer linear Programming, Dynamic Programming, Sensitivity analysis.
Assignment problem: Hungarian's algorithm, Degeneracy, applications, unbalanced problems, traveling salesman problem.
Classical optimization techniques: Single variable optimization with and without constraints, multi – variable optimization without constraints, multi – variable optimization with constraints – method of Penalty methods Lagrange multipliers, Kuhn-Tucker conditions.
Numerical methods for optimization: Nelder Mead's Simplex search method, Gradient of a function, Steepest descent method, Newton's method, Conjugate Gradient methods for handling constraints.
Genetic algorithm (GA) : Differences and similarities between conventional and evolutionary algorithms, working principle, reproduction, crossover, mutation, termination criteria, different reproduction and crossover operators, GA for constrained optimization, draw backs of GA
Genetic Programming (GP): Principles of genetic programming, terminal sets, functional sets, differences between GA & GP, random population generation, solving differential equations using GP.
CPM/PERT: Simulation of CPM/PERT network, Analysis of an activity network, Simulation of inventory system and manufacturing system

Text Books / References:

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. Engineering Optimization: Theory and Practice, 4th Ed., 2009, S.S. Rao, Wieley Eastern Ltd.
4. Optimization: Theory and Practice, 2004, MC Joshi, KM Moudgalya, Narosa.

5. Introduction to Optimization, 1988, Beale, John Wiley.
6. Optimal design – Jasbir Arora, Mc Graw Hill (International) Publishers
7. Optimization for Engineering Design – Kalyanmoy Deb, PHI Publishers
8. Genetic algorithms in Search, Optimization, and Machine learning – D.E.Goldberg, Addison Wesley Publishers
9. Genetic Programming- Koza
10. A Field Guide to Genetic Programming, Riccardo Poli, William B. Langdon, Nicholas F. McPhee
11. Genetic Programming Theory and Practice by Rick Riolo, Bill Worzel, Kluwer Academic Publishers
12. Genetic Programming: An Introduction, Wolfgang Banzhaf, Peter Nordin, Robert E. Keller, Frank D. Francone, Morgan Kaufmann Publishers
13. Multi objective Genetic algorithms - Kalyanmoy Deb, PHI Publisher
14. Numerical Methods and Optimization, Hari Arora, S.K. Kataria & Sons
15. Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer

AM 604 Advanced Statistical Techniques

Course Code	**AM 604**
Course Name	***Advanced Statistical Techniques***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
CO1: Students can 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: Students are be able to understand the importance of Probability Distributions such as Binomial, Poisson, Normal and Exponential Distributions and their properties and problems on special probability distributions. CO3: Students are be able to analyze and appreciate the statistical theory behind Curve fitting, regression modeling and Chi Square Test, student test & Fisherman test. CO4: Students are be able to understand the theory behind Design and Analysis of Experiments: Need for conducting Experiments, and their possible applications.	

Probability and Probability Distributions: Basic concepts of Probability , Discrete Probability Distributions (Binomial, Poisson etc.), Continuous Probability Distributions (Normal, Exponential, Weibull etc.).

Inferential Statistics: Theory of Estimation, Sampling Distribution, Tests of Hypothesis (one sample t, two sample t etc.), Chi Square Test.

Introduction to Statistical modelling.

Regression modeling for Normal response and quantitative explanatory: Variables, Simple and Multiple regressions, Model building and validation Comparison of regressions.

Stochastic process: Basic idea of random processes, Stationary, Markov processes, Markov chains and applications, Introduction to ergodicity.

Introduction to Design and Analysis of Experiments: Need for conducting Experiments, Applications of experiments, Basic Principles of Experiments, Road Map to conduct efficient experiments Terminologies associated with experiments.

Text/References

1. Stochastic Process, 3rd Ed., 2010, J. Medhi, New Age Science Ltd.
2. Design and Analysis of Experiments, 8th Ed., 2012, Douglas C. Montgomery, Wiley.
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. All of Statistics: A Concise Course in Statistical Inference, 2003, Larry Wasserman, Springer.
6. Introduction to Statistical Modelling, 2010, W. J. Krzanowski, Oxford university press.
7. Schaum's outlines Probability and statistics, 4th Ed., 2013, Murray R. Speigel, John Schiller, R Alu Srinivasan, Tata McGraw Hill.

AM 605 Computer Graphics

Course Code	**AM 605**
Course Name	***Computer Graphics***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
CO1: Students will get an overview on applications of computer graphics, the different software and hardware configurations that will be required to generate graphics. CO2: Students will learn the algorithms for generating various output primitives like Points, Lines, Circles, Ellipses, Colour filling algorithms, etc. CO3: Students acquire the knowledge on various transformations such as translation, rotations, scaling, composite transformations, etc. Students will learn the different techniques for detecting the visible surfaces CO4: Students will learn the different process involved in computer animation, and will gets hands on sessions by implementing some of the computer graphics algorithms using openGL library.	

Introduction: Application areas of Computer Graphics, overview of graphics systems, video-display devices, raster-scan systems, random scan systems, graphics monitors and work stations and input devices
Output primitives: Points and lines, line drawing algorithms, mid-point circle and ellipse algorithms. Filled area primitives: Scan line polygon fill algorithm, boundary-fill and flood-fill algorithms.
2-D Geometrical transforms: Translation, scaling, rotation, reflection and shear transformations, matrix representations and homogeneous coordinates, composite transforms, transformations between coordinate systems.
2-D Viewing: The viewing pipeline, viewing coordinate reference frame, window to view-port coordinate transformation, viewing functions, Cohen-Sutherland and Cyrus-beck line clipping algorithms, Sutherland –Hodgman polygon clipping algorithm.
3-D Object representation: Polygon surfaces, quadric surfaces, spline representation, Hermite curve, Bezier curve and B-spline curves, Bezier and B-spline surfaces. Basic illumination models, polygon rendering methods.
3-D Geometric transformations: Translation, rotation, scaling, reflection and shear transformations, composite transformations, 3-D viewing: Viewing pipeline, viewing coordinates, view volume and general projection transforms and clipping.
Visible surface detection methods: Classification, back-face detection, depth-buffer, scan-line, depth sorting, BSP-tree methods, area sub-division and octree methods

Computer animation: Design of animation sequence, general computer animation functions, raster animation, computer animation languages, key frame systems, motion specifications
Text / References:

1. Computer Graphics, Donald Hearn and M. Pauline Baker, Pearson education, C version.
2. Computer Graphics Principles & practice, second edition in C, Foley, VanDam, Feiner and Hughes, Pearson Education.
3. Computer Graphics Second edition, Zhigand xiang, Roy Plastock, Schaum’s outlines, Tata Mc Graw hill edition.
4. Procedural elements for Computer Graphics, David F Rogers, Tata Mc Graw hill, 2nd edition.
5. Principles of Interactive Computer Graphics, Neuman and Sproul, TMH.
6. Principles of Computer Graphics, Shalini, Govil-Pai, Springer.
7. Computer Graphics, with OpenGL Hearn and Baker, - Pearson
8. Computer Graphics, Sinha & Udai, - TMH

AM 606 Mathematical Methods

Course Code	**AM 606**
Course Name	***Mathematical Methods***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

CO1: Students will understand and know the analytical techniques to solve the differential equations of specific nature. Also, students will understand the power series representation of various functions like Bessel / Legendre when the given differential equation is not in the standard form.

CO2: Students will learn Laplace and Fourier transforms techniques of various functions to Solve ODEs further Will be able apply to model physical phenomenon and then solve.

CO3: Will be able to find rank of a matrix, able to diagonalize a matrix and give the related interpretation, can find the basis and dimension of a vector space, Image and kernel of a linear transformation.

CO4: Students will learn what is Haar and Shannon wavelets are, and how they are used to represent and transform to apply them in various applications.

Differential Equations: Review of solution methods for first order as well as second and Higher order equations, Power Series methods with properties of Bessel functions and Legendre polynomials. **Applications:** Orthogonal Trajectories, Population Growth and Decay, Newton's Law of Cooling, Free Falling Bodies. Simple Harmonic Motion, Damped Motion, Forced Motion, Other Applications in Electronics and Pendulum Problem.

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 and symmetric matrices, Quadratic forms.

Transform Techniques: Over View of Laplace Transforms – Inverse Laplace Transforms – Fourier transform: Flourier integral formula – Fourier transform – Inversion theorem for complex Fourier transform – Fourier Sine and Consine transforms – Inversion formulae – Finite Fourier sine and Cosine Transform – Inversion formulae – Application of transform techniqes to solutions of differential equations, integral equations and boundary value problems. Wavelets – The Haar wavelets – A wavelets expansion – Multiresolution analysis with Haar Wavelets – General construction of wavelets and multiresolution analysis - Shannon wavelets.

Texts / References:

1. Advanced Engineering Mathematics, 10th Ed, 2005, Erwin Kreyszig Wiley Eastern.
2. Linear Algebra and its Applications, 4th Ed., 2008, Gilbert-Strang, Academic press.
3. Applied Linear Algebra & Matrix Analysis, 2007, Thomas S Shores, Springer.
4. Advanced Engineering Mathematics, Peter V. O'Neil Thomson Brooks /Cole
5. Ordinary Differential Equations by Deo and Raghavendra
6. Fourier analysis with Applications of boundary value problems schaum series.
7. Integral Transforms by Goyal and Gupta.

AM 607 Mathematics for Engineers

Course Code	**AM 607**
Course Name	***Mathematics for Engineers***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
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	

Elements of Probability and Statistics: Basic concepts of Probability, Discrete Probability Distributions (Binomial, Poisson etc.), Continuous Probability Distributions (Normal, Exponential, etc.,).

Components of Operations Research:

Introduction to Operations Research, Linear programming (Simplex Method, Revised Simplex Method, Dual simplex, Duality theory), Transportation Models.

Linear Algebra:

General (real) vector spaces, Subspaces, Linear Independence of Vectors, Basis and Dimension, Linear Transformations, Span, Norms, Orthogonal basis and Gram-Schmidt Orthogonalization.

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.

Transform Techniques :

Overview of Laplace transforms, Fourier Transforms, Z transform.

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

Texts / References:
13. Advanced Engineering Mathematics, 11th Ed, 2010, Erwin Kreyszig, Wiley Eastern.
14. Linear Algebra and its Applications, 4th Ed., 2008, Gilbert Strang, Academic Press.
15. Numerical Methods for Scientists and Engineers, Joe D. Hoffman, Marcel Dekker Inc.
16. Numerical Methods for Engineers, Sixth Edition, Steven Chapra and Raymond Canale, McGraw-Hill Education
17. Elements of Numerical Analysis, 2nd Edition, Radhey S. Gupta**,** Cambridge University Press
18. Numerical Solutions of Partial Differential Equations: An Introduction, 2nd Ed., 2005, K. W. Morton, D. F. Mayers, Cambridge University Press.
19. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
20. Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.
21. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
22. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
23. Differential Equations and Dynamical Systems, Texts in Applied Mathematics, L. Perko, 3rd Ed., Vol. 7, 2006, Springer Verlag, New York.
24. .S. Gupta.. Calculus of Variation, Prentice Hall of India Pvt. Ltd.

AM 621 Advanced Modelling Techniques

Course Code	**AM 621**
Course Name	***Advanced Modelling Techniques***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
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 i9s inherent in large no. of models. CO3: Students are be able to analyze and appreciate the mathematics behind the variety neural networks such as perceptron learning, back propagation methods etc., that can be applied to solve a specific model. CO4: Students are be able to understand the theory behind chaos mathematically using a specific water wheel model. Also, to understand the theory behind fractals and their possible applications	

Fuzzy logic: Basic concepts of fuzzy set, Operation on fuzzy sets, Fuzzy numbers Fuzzy relation, Fuzzification, Fuzzy logic as generalization of two valued logic, Fuzzy system, fuzzy control, fuzzy clustering.

Artificial Neural Networks – Introduction, Neural network representation, Appropriate problems for neural network learning, Perceptions, Multilayer networks and the back propagation algorithm, Remarks on the back propagation algorithm, An illustrative example face recognition Advanced topics in artificial neural networks

Dynamics of Chaos: Introduction to chaos, Lorenz system, Lorenz attractor, Dimension of chaotic attractor, applications in communications.
Fractals: Introduction to fractals, Types of fractal dimensions, Generation of fractals by mathematical approach, Julia and Mandelbrot sets.

Text/References

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.
3. Neural fuzzy systems: A Neurofuzzy Synergism to Intelligent Systems, 1996, Chin- Teng Lin and C.S.G. Lee, Prentice Hall International, INC.
4. Encounter With Chaos, 1992, Denny Gulick , McGraw Hill Inc.

AM 622 Simulation of Linear and Nonlinear Systems

Course Code	**AM 622**
Course Name	***Simulation of Linear and Nonlinear Systems***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
CO1: Students can understand the basics concepts of real systems, mathematical model, types of models, simulation and their applications. CO2: Students are be able to understand the importance of Generation of random numbers, Pseudo random numbers, generation of random variates using discrete and continuous probability distributions such as uniform, triangular. CO3: Students are be able to analyze and appreciate the uniformity and independence properties using testing of hypothesis and Chi-square, auto correlation tests. CO4: Students are be able to understand the simulation theory related to Queuing, Inventory and CPM/PERT and implement industrial and real-world problems.	

Simulation of single server and multiple server queuing system. Design (component & organisation) of a simulation experiment. Rational selection of input distribution. Output data analysis. Variance reduction techniques, Model validation. Discrete event systems, Time advance mechanism, Simulation, Monte Carlo & Stochastic Simulation
Generation of random numbers, Pseudo random numbers, Test for random number simulation of probability distribution.
Discrete event simulation: simulation of single server and multiple server queuing system.
Concept of systems, Classification of systems, General Properties of Linear and nonlinear systems.
Periodic orbits, Poincare Bendixson criterion, limit cycle, bifurcation, Lyapunov Stability, basic stability and instability theorems, uniform stability, asymptotic stability, exponential stability

Text/References

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.
5. System Modelling and Computer Simulation, 1996, Kheir N.A, Marcell Dekker.
6. Discrete-Event System Simulation, 5th Ed., 2009, Jerry Banks, John Carson, Barry L. Nelson, David Nicol, Prentice Hall
7. Operations Research: An Introduction, 2002, Taha H.A, Prentice Hall.

AM 623 Machine Learning

Course Code	**AM 623**
Course Name	***Machine Learning***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

CO1: Understand the scenarios where machine learning algorithms can and cannot be used. Understand different types of machine learning algorithms namely unsupervised, supervised, reinforcement learning algorithms, and gets exposure to scenarios/applications where these algorithms can be applied.

CO2: Students will learn the concepts of Regression, Classification and Clustering algorithms, and how to choose metrics to evaluate the performance of various machine learning models.

CO3: Students will 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: Students acquire the 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.

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

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

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

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

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,

Reinforcement Learning – Introduction, the Learning Task, Q Learning, Non-Deterministic, Rewards and Actions, Temporal Difference Learning, Generalizing from Examples, Relationship to Dynamic Programming.

Text / 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

AM 624 Tensor Analysis and Engineering Applications

Course Code	**AM 624**
Course Name	***Tensor Analysis and Engineering Applications***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
CO1: Students will learn basic and advanced concepts of tensor analysis in engineering problems. CO2: Students will learn the concepts of truss-related problems. CO3: Students will learn applications of tensors in artificial intelligence, machine learning, and data science etc. CO4: Students will also learn tensor analysis of differential equations.	

Definition and algebra of tensors. Summation convention – Contravariant and covaraiant vectors – Contraction of tensors – Inner product – Quotient law – Metric tensor – Chrirstoffel symbols – Covariant differentiation – Gradient, divergence and curl. Dyadic representation in Cartesian and general components. Calculus of tensor fields in curvilinear coordinates. Derivation and application of the basic equations of heat conduction, rigid body mechanics, elasticity, fluid mechanics & electromagnetism in tensor form.

Text / References:

1. Tensor Calculus - Barry Spain ., Radha Publishing House.
2. Mathematical Methods in Physics & Engg.,- John W.Dettman., Mc-Grawhill.
3. Tensor Calculus – U.C.De, Absos Ali Shaikh & Joydeep Sengupta., Narosa Publications.
4. Tensor Analysis with Application in Mechanics – Leonid.P.Levedev, Michael.J.Cloud Victoria eremeyev; World Scientific Publication.
5. Applications of Tensor Analysis – A.J.MeConnell, Dover Publications.
6. Tensor Analysis with Applications – Jafer Ahsan, Annamaya Publications.

AM 625 Digital Images Processing

Course Code	**AM 625**
Course Name	***Digital Images Processing***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

CO1: The students get an understanding of basic image model, and will learn basic image processing techniques to analyze the image in terms of histogram, contrast, sharpness, etc.

CO2: The students will 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: The students will learn image segmentation algorithms, understands the need for image compression and learn the spatial and frequency domain techniques used for image compression.

CO4: The students learn different feature extraction techniques employed for image analysis and recognition, and gets an overview on applications of image processing in Machine vision.

Digital Image Fundamentals: Introduction – Origin –Steps in Digital Image Processing – Components; Elements of Visual Perception – Light and Electromagnetic Spectrum – Image Sensing and Acquisition – Image Sampling and Quantization – Relationships between pixels.
Image Enhancement: Spatial Domain: Gray level transformations – Histogram processing – Basics of Spatial Filtering–Smoothing and Sharpening Spatial Filtering – Frequency Domain: Introduction to Fourier Transform – Smoothing and Sharpening frequency domain filters – Ideal, Butterworth and Gaussian filters.
Image Restoration: Noise models – Mean filters – Order Statistics – Adaptive filters – Band reject – Band pass – Notch – Optimum notch filtering – Inverse Filtering – Constrained Least Square Filtering – Wiener filtering.
Morphological image processing: Dilation, Erosion, Opening, Closing, Applications to; Boundary extraction, Region filling, Extraction of connected components.
Image Compression: Fundamentals – Image Compression models – Error Free Compression – Variable Length Coding –Bit – Plane Coding – Lossless Predictive Coding – Lossy Compression – Lossy Predictive Coding –Wavelet Coding – Compression Standards – JPEG2000.
Image Segmentation and Representation: Segmentation – Detection of Discontinuities – Edge Linking and Boundary detection – Region based segmentation; Representation – Boundary descriptors – Simple Descriptors – Shape numbers –Regional descriptors – Simple and Topological Descriptors – Introduction

to Image Processing Toolbox – Practice of Image Processing Toolbox – Case studies–Various Image Processing Techniques.
Object recognition: Decision-theoretic methods.

Text / References

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.
3. Digital Picture Processing, 2nd Ed., 1982, A. Rosenfeld, A. C. Kak, Academic Press.
4. Fundamentals of Digital Image Processing, 1st Ed., 1989, A.K. Jain, Prentice Hall of India.
5. Pattern Classification and Scene Analysis, 1973, R. O. Duda, P. E. Hart, John Wiley.
6. Pattern Recognition, Applications to Large Data-Set Problems, 1984, Sing-Tze Bow, Marcel Dekker.

AM 626 Computational Heat and Mass Transfer

Course Code	**AM 626**
Course Name	***Computational Heat and Mass Transfer***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
CO1: The students have would get an intuitive idea about the practical applications of convective fluid flow into various industrial field. CO2: After completion of this course, students can have explicit knowledge about mixed convection phenomena CO3: The computation of convective heat and mass transfer analysis would be easy for students CO4: The numerical analysis associated with the flow characteristics could be helpful in the other branches of CFD	

Philosophy of Computational Fluid Dynamics: Introduction to CFD, CFD- a research tool, CFD- a design tool, Applications and Advantages of CFD, The basic governing fluid flow equations in differential form, Models of Fluid flow, Concept of Substantial derivative, Navier-Stoke‘s model and Euler‘s model equations.
Convective Heat Transfer:
Introduction to convection, review of conservation equations - Forced convection in laminar flow - Exact and approximate solutions of Boundary layer energy equation for plane isothermal plate in longitudinal flow - problems. Forced convection heat transfer in laminar tube flow - forced convection in turbulent flow – Internal Flows-Correlations-Problems. Approximate analysis of laminar free convective heat transfer on a vertical plate-external flows-correlations-problems.
Convective Mass Transfer
Definitions of concentration and velocities relevant to mass transfer, Fick's law, species conservation equation in different forms. Steady state diffusion in dilute solutions in stationary media, transient diffusion in dilute solutions in stationary media, one dimensional non dilute diffusion in gases with one component stationary. Convective mass transfer - governing equations-forced diffusion from flat plate-Dimension less correlation’s for mass transfer. Simultaneous heat and mass transfer - analogy between heat, mass and momentum transfer

Finite Element Method Technique: Formulation Techniques: Methodology, Engineering problems and governing differential equations, finite elements, Variational methods-potential energy method, Raleigh Ritz method, strong and weak forms, Galerkin and weighted residual methods, Piecewise Defined Shape functions, Essential and natural boundary conditions. One-dimensional finite element methods: Bar elements. Element matrices, assembling of global stiffness matrix, Application of boundary conditions, Quadratic Element, Implementation of the FEM - The Solution Procedure.
Finite Element Method Techniques in Heat & Mass Transfer problems: One-dimensional, conduction and convection problems examples:. Two dimensional problems: CST, LST, four noded and eight 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.

Text / References

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.
4. Computational Fluid Dynamics: A Practical Approach, 1st Ed., 2008, Jiyuan Tu, Guan Heng Yeoh, Chaoqun Liu, Butterworth-Heinemann.
5. Computational Methods for Fluid Dynamics, 3rd Ed., 2013, J. H. Ferziger, M. Peric, Springer.
6. Convection in Porous Media, 4th Ed., 2013, Donald A. Nield, Adrian Bejan, Springer.
7. Convective Heat and Mass Transfer, 1st Ed., 2011, S. Mostafa Ghiaasiaan, Cambridge University Press.
8. Fundamentals of Heat & Mass Transfer by Thirumaleshwar, Pearson
9. Conduction Heat transfer, Poulikakos, Prentice Hall, 1994.
10. Analytical methods in Conduction Heat Transfer, G.E. Mayers, McGraw Hill, 1971.
11. Convective Heat and Mass Transfer, Kays W M and Crawford M E, McGraw Hill Int Edition, 3rd edition, 1993.
12. Introduction to Convective Mass Transfer, Spalding D B, McGraw Hill, 1963.

AM 627 Introduction to Non-Newtonian Fluids

Course Code	**AM 627**
Course Name	***Introduction to Non-Newtonian Fluids***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
CO1:The applications areas of non-newtonian fluids are broad and this course could help students to apply the theoretical knowledge into the industrial fields CO2: The thermophysical properties of various nanofluids are 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 managements are very well utilized such nanofluids that fulfil their aim. Thus, this course can help to choa perfect applicable fluid in these areas

Kinematics of Fluids Flow: Introduction, Velocity Gradient Tensor, Rate of Deformation Tensor, Analysis of Strain Rates, Spin Tensor, Curvature-Twist Rate Tensor, Objective Tensors, Balance of Mass.
Governing Equations: Introduction, Measure of Mechanical Interactions, Euler's Laws of Motion, Stress and Couple Stress Vectors, Stress and Couple Stress Tensors, Cauchy's Laws of Motion, Analysis of Stress, Energy Balance Equations, Entropy Inequality.
Couple Stress Fluids: Introduction, Constitutive Equations, Equations of Motion, Boundary Conditions, Steady Flow between Parallel Plates, Steady Dimensional Flow between Two Co-axial Cylinders, Poiseuille Flow through Circular Pipes, Creeping Flow Past a Sphere, Some Time- Dependent Flows, Hydromagnetic Channel Flows.
Micro Fluids: Introduction, Description of Micro motion, Kinematics of Deformation, Conservation of Mass, Balance of Moments, Micro Inertia Moments, Balance of Energy, Entropy Inequality, Constitutive Equations for Micro Fluids, Linear Theory of Micro Fluids, Equations of Motions.
Micropolar Fluids: Introduction, Skew-symmetric of the Gyration Tensor and Micro Isotropy, Micropolar Fluids, Thermodynamics of Micropolar Fluids, Equations of Motion, Boundary and Initial Conditions, Two Limiting Cases, Steady Flow between Parallel Plates, Steady Couette Flow between Two Co-axial Cylinders, Pipe Poiseuille Flow, Micropolar Fluids with Stretch.

Text / References

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
3. Micropolar Fluids Theory and Applications, 1999, Grzegorz Lukaszewicz, Birkhauser Boston.
4. Fluid Dynamics, 3rd Ed., 2004, William F. Hughes, John A. Brighton, Tata McGraw- Hill.

AM 628 Computational Number Theory and Cryptography

Course Code	**AM 628**
Course Name	***Computational Number Theory and Cryptography***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
CO1: Students will learn computational methods in Algebra and Number Theory. CO2: To understand fundamental number-theoretic algorithms such as the Euclidean algorithm, the Chinese Remainder algorithm, binary powering, and algorithms for integer arithmetic. CO3: To 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: To understand fundamental algorithms for symmetric key and public-key cryptography.

Introduction: Attacks, Services and Mechanisms, Security attacks, Security services, A Model for Internetwork security. Classical Techniques: Conventional Encryption model, Steganography, Conventional Encryption Principles, Conventional encryption algorithms, cipher block modes of operation, location of encryption devices.

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.

Factorization and Primality Testing: Complexity of Number Theoretic Algorithms, Fermat's Factorization, Kraitchik's Improvement, Pollard Rho Algorithm, Legendre and Jacobi Symbols, Computing Legendre symbols, Primitive Roots, Pseudo Primality Testing, Miller-Rabin Algorithm**,** Quadratic Reciprocity Law

Finite fields: Groups, Fields, Finite Fields, Arithmetic in Finite Field, Finding Multiplicative Inverses in finite fields, Binary Fields and their application in Cryptosystems, Primitive roots.

Cryptography: Introduction to Cryptosystems, Classical Ciphers, Cryptanalysis of Classical ciphers, LFSR based stream ciphers. Shannon's Theory**,** Public Key Cryptography, RSA Cryptosystem, Diffie-Helman Key Exchange, Rabin Cryptosystem, Knapsack Ciphers, Digital Signature, Secret Sharing, ElGamal Cryptosystem, Elliptic Curve Cryptography.

Elliptic Curve Cryptography: Introduction to Elliptic Curves, Geometry of Elliptic curves over Reals, Weierstrass Normal form, Point at infinity, Elliptic Curves over Finite fields, Group structure, Discrete Log problem for Elliptic curves, Factorization using Elliptic Curve, Advantage of Elliptic Curve Cryptography over other Public Key Cryptosystems.

Text / References

1. N. Koblitz, A Course in Number Theory and Cryptography, Springer 2006.
2. I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to theory of numbers, John Wiley & Sons, Inc 2006.
3. L. C. Washington, Elliptic curves: number theory and cryptography, Chapman & Hall/CRC, 2003.
4. J. Silverman and J. Tate, Rational Points on Elliptic Curves, Springer-Verlag, 2005.
5. D. Hankerson, A. Menezes and S. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag, 2004.
6. J. Pipher, J. Hoffstein and J. H. Silverman , An Introduction to Mathematical Cryptography, Springer-Verlag, 2008.
7. G.A. Jones and J.M. Jones, Elementary Number Theory, Springer-Verlag, 1998.
8. R.A. Mollin, An Introduction to Cryptography, Chapman & Hall, 2001.
9. Song Y. Yan: Number Theory for Computing, Springer-Verlag, Second Edition,2002.

10. T. H. Cormen, C. E. Leiserson, and R. L. Rivest: Introduction to Algorithms, Second Edition, Prentice Hall of India, 1994.
11. K. Rosen: Elementary Theory of Numbers, Fifth Edition, Addison Wesley, 2004.
12. D. M. Bressoud: Factorization and Primality Testing, Springer-Verlag, 1989.

AM 629 Calculus of Variations and Integral Equations

Course Code	**AM 629**
Course Name	***Calculus of Variations and Integral Equations***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
CO1: Students will learn the core concepts of multi variable calculus and integral equations with voltera and freedholm alternatives. CO2: Students will learn the applications of these techniques in several engineering problems. CO3: Students will learn the Greens functions, and Galerkin and Ritz approach of variational equations. CO4: Students will also learn the minimum surface of revolution and fundamental results of calculus of variations	

Linear integral equations, Some basic identities, Initial value problems reduced to Volterra integral equations, Methods of successive substitution and successive approximation to solve Volterra integral equations of second kind, Iterated kernels and Neumann series for Volterra equations. Resolvent kernel as a series in, Laplace transforms method for a difference kernel, Solution of a Volterra integral equation of the first kind.

Boundary value problems reduced to Fredholm integral equations, Methods of successive approximation and successive substitution to solve Fredholm equations of second kind, Iterated kernels and Neumann series for Fredholm equations. Resolvent kernel as a sum of series. Fredholm Resolvent kernel as a ratio of two series. Fredholm equations with separable kernels, Approximation of a kernel by a separable kernel, Fredholm Alternative, Non homogenous Fredholm equations with degenerate kernels.

Green's function, Use of method of variation of parameters to construct the Green's function for a non-homogeneous linear second order boundary value problem, Basic four properties of the Green's function, Orthogonal series representation of Green's function, Alternate procedure for construction of the Green's function by using its basic four properties. Reduction of a boundary value problem to a Fredholm integral equation with kernel as Green's function. Hilbert-Schmidt theory for symmetric kernels.

Motivating problems of calculus of variations, Shortest distance, Minimum surface of revolution, Branchistochrone problem, Isoperimetric problem, Geodesic. Fundamental lemma of calculus of variations, Euler's equation for one dependant function and its generalization to 'n' dependant functions and to higher order derivatives, Conditional extremum under geometric constraints and under integral constraints.

Text / References

1. A.J. Jerri. Introduction to Integral Equations with Applications. Wiley-Interscience.
2. R.P. Kanwal. Linear Integral Equations: Theory and Techniques. New York: Academic Press.

3. J.M. Gelfand and S.V. Fomin. Calculus of Variations. Englewood Cliffs: Prentice-Hall, 1963.
4. Weinstock . Calculus of Variations. McGraw-Hall.
5. Abdul-Majid Wazwaz. A First Course in Integral Equations. World Scientific Pub.
6. P. David and S.G. David. Stirling Integral Equations. Cambridge University Press.

AM 630 Domain Decomposition Methods

Course Code	**AM 630**
Course Name	***Domain Decomposition Methods***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

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

The mathematical Foundation of Domain decomposition Methods. Discretised equations and Domain Decomposition Methods. Schur Complement and Iterative Sub-structuring Algorithms. Iterative Domain Decomposition Methods. Time-dependent problems. Multilevel and local grid refinement methods.

Text / References

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.
3. Domain Decomposition Methods Algorithms and Theory, 2004, A. Toselli and O. Widlund, Springer-Verlag.
4. Domain Decomposition Methods for the Numerical Solution of Partial Differential Equations, 2008, Tarek P.A. Mathew, Springer-Verlag Berlin Heidelberg.

AM 631 Multigrid Methods

Course Code	**AM 631**
Course Name	***Multigrid Methods***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

CO1: Students will learn the core concepts of multigrid methods with local and global processing. CO2: Students will learn the convergence analysis and classical and advanced relaxation methods CO3: Students will learn the grid refinement algorithms and fourier analysis of the convergence results. CO4: Students will also learn the anisotropic problems and their practical applications.

Basic concepts, local and global processing, discretization, 1D model problem and its direct and iterative solution, convergence analysis, 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, nonlinear and anisotropic problems, advanced techniques, algebraic approach, applications.

Text / References:

1. B. Smith, P. Bjorstad, W. Gropp, *Domain Decomposition: Parallel Multilevel Methods for Elliptic Partial Differential Equations, C*ambridge, 1996.
2. E. Henson, and S. F. McCormick: A Multigrid Tutorial, 2nd ed., SIAM, 2000.
3. U. Trottenberg, C. W. Oosterlee, and A. Schueller: Multigrid, Academic Press, 2001.
4. W. Hackbusch and U. Trottenberg eds.: Multigrid Methods, Springer-Verlag, Berlin, 1982.
5. P. Wesseling: An Introduction to Multigrid Methods, Wiley, Chichester, 1992.
6. W. Hackbusch: Multi-grid Methods and Applications, Springer, Berlin 1985.
7. Brandt: Multi-level Adaptive Solutions to Boundary-Value Problems, Math. Comput, Vol. 31, 333-390, 1977.

AM 632 Ballistics

Course Code	**AM 632**
Course Name	***Ballistics***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**
CO1: Have a knowledge and understanding of Newtonian mechanics relating to the flight of projectiles. Energy considerations in ballistics. Weapon mechanisms. Ammunition. Overview of the main stages of ballistics (Internal, Intermediate, External and Terminal). CO2: The application of mechanics to different scenarios of ballistics. CO3: The application of law to ballistics. CO4: Develop practical skills in ballistics further, for higher level ballistics modules.	

Explosives: Explosive compounds and explosive mixtures-classification of explosives: Measurement of various explosive parameters

Internal Ballistics: General introduction –Propellants-Driving Band engraving process, and the resistance to the in–bore motion of a projectile- Heating of gun barrel- Heat conduction in thick walled barrels- Numerical solution for heat conduction- Wear in gun barrels- Prediction of pressure history and muzzle velocity- The internal ballistics of leaking gun.
External Ballistics: Projectile Aerodynamics: General introduction-yaw-The aerodynamic forces and moments acting on a projectile-linearised aerodynamics-centre of pressure and stability-Aerodynamic coefficients-Drag laws-Angular motion of projectiles-Gyroscopic stability-Yawing behaviour-The linearised theory of yawing motion-projectiles with slight configurational asymmetries-projectiles not obeying classical linear theory.
Projectile Transitional Motion: Motion in vacuum-Motion of point mass-Trajectory modelling-constant corrections to the plane-particle trajectory, biases-variable corrections to the plane-particle trajectory, dispersion-the effect of wind.
Terminal Ballistics: Kinetic Energy projectiles: Penetration into resisting medium-Empirical formulae for the prediction of penetration-Analytical models of failure modes-Numerical methods-plate charges.
Design and Defeat of Armour: Introduction –Mechanical property requirements-Armour material Characteristics –Armour structure-stress-strain relationship-Waves in rods-Defeat of armour-Failure
Wound Ballistics: Threshold velocity for penetration of skin, flesh, bones- Nature of wounds on entry, exit-Explosive wounds- Evaluation of injuries caused due to shot gun, rifle, hand guns and country made firearms- Method of measurement of wound ballistic parameters- post mortem and ante- mortem firearm injuries.

Text / References:

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, Malcom J Dodd, CRC press, Taylor & Francis publications
5. Firearms in criminal investigation and trials, Dr. BR Sharma, 3rd Edition, Universal Law publishing Co. Pvt Ltd.
6. Gunshot wounds- practical aspects of Firearms. Ballistics and Forensic Techniques, Vincent JM DiMaio, Elsevier Science publishing Co. Inc
7. Wound Ballistics and the Scientific Background, Karl G Sellier & Beat P Kneubuehl Elseviour Science publishing Co. Inc.

AM 633 Bio-Mechanics

Course Code	**AM 633**
Course Name	***Bio-Mechanics***
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

CO1: Students will learn the mathematical aspects of the Bio-mechanics and toll for the investigations in blood flow through the arteries and heart.

CO2: Students will learn the mass conservation and energy conservation with the momentum conservation in the blood flow problems

CO3: Students will learn the Rheological properties of bio fluid dynamics concepts

CO4: Students will also learn the transport phenomena and cardiovascular system.

Biomechanics, Method of approach, Tools of investigation, Stresses and rates of strain, Constitutive equations, Newtonian viscous fluid, Hookean elastic solid, Viscoelasticity, Biological transport process, Basic momentum, Heat and mass transport concepts. Conservation laws; mass conservation, Momentum conservation, Energy conservation.

Introduction - Continuum Approach - Blood Flow in Heart, Lung, Arteries and Veins: Introduction - The geometry of the circulation system - Field equations and Boundary conditions, Pulsatile Flow in Arteries - Progressive

The Rheological Properties of Blood Bio-fluid dynamics concept, Transport phenomena and the cardiovascular system.

Biofluid mechanics of organ systems, The lungs, The Kidneys and the lever. Micro-circulation, Pressure distribution in micro vessels, Pressure in the intesstitial space, Velocity distribution in micro vessels, The velocity-Hemotocrit relationship, mechanics of flow at very low Reynolds numbers.

Text / References:

1. Biomechanics, Springer-verlag: Y.C.Fung
2. Bio-fluid Dynamics Taylor and Francis: Clement Kluinstreuer
3. Frontier in Mathematical Biology: S.A.Levin
4. Biomathematics: Ricciardi

M.Tech. (Data Science)

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.

Department of Applied Mathematics offers a two year Interdisciplinary M. Tech. (Modelling & Simulation) programme, and also offers a Doctoral Degree programme in the areas of Applied Mathematics.

The Department faculty members have been actively involved in the research in different fields of applied mathematics such as ballistics, flight dynamics, hydro-dynamics, hydro-ballistics, Numerical Methods and Optimization, Statistics, Probability, Neural Network, Fuzzy Logic and Genetic Algorithm, Parallel Computing, Cryptography and Machine Learning.

This MTech. (Data Sciences) programme is of two years duration where the student undergoes basic training in the subjects(Core and Elective) related to **probability and statistics, inference, regression,**

optimization, statistical simulation and data analysis, sampling theory (Math and Statistics); management decision analysis, decision models, game theory (IME, Economics), programming, algorithms, operating systems, databases, signal processing, machine learning and data mining techniques of data science (CS, EE). Information Theory (information, entropy, conditional information, coding), Multi-resolution (multirate) signal processing (wavelets, pyramids), ANN, SVM, Projection pursuit Artificial Intelligence and DSS through classroom teaching in the first and second year. During this period the student is also exposed to various simulation tools and practicals. 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.

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 explo sive 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 in CSE / IT / ECE / ME / AE. OR MSc / MS degree in CS / IT / Mathematics / Physics / Electronics Provided 1) Mathematics is one of the subject at the graduate level and 2) Knowledge in computer programming is desirable

CSE - Computer Science Engineering
IT - Information Technology
AE - Aerospace Engineering
ECE - Electronics & Communication Engineering
ME - Mechanical Engineering

Semester I:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T /P	
1.	AM 603D	Computer Oriented Optimization Methods	3	1	4
2.	AM 604D	Statistical Computing for Data Science	3	1	4
3.	AM 606D	Scientific Computing	3	1	4
4.	AM 607D	Data Structures and Algorithms with C	3	1	4
5.	CE 615A	Intelligent Algorithms	3	1	4
6.	CE 696A	Artificial Intelligence and DSS	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 623D	Machine Learning	3	1	4
2.	AM 624D	Data Science: Tools and Techniques	3	1	4
3.	CE 694	Big Data Analysis and Algorithms	3	1	4
4.		Elective I (Department Electives)	3	1	4
5.		Elective II (Open Elective)	3	1	4
6.		Elective III (Open Elective)	3	1	4
7.	PGC-602	Audit Course	2	0	0
		TOTAL	20	6	24

Semester III:

Sl. No.	Course Code	Course Name	Contact hours/week		Credits
			L	T / P	
1.	AM 651D	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 652D	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
	AM 609D	**Data Science: Industrial Perspectives#**
	AM 625D	Image and Video Analytics
	AM 627D	Information Theory and Coding
	AM 628D	Computational Number Theory and Cryptography
	CE 605	Applied Artificial Intelligent Systems
	CE 607	Decision Support Systems

	CE 610	Information Retrieval Systems
	CE 631	Deep Learning
	CE 632	Computer Vision
	CE 688	Game Theory
	CE 690	Parallel & Distributed Systems
	CE 691	Secure Wireless Sensor Networks
	CE 699	Internet of things
	EE 610D	Multiresolution Signal Processing
	AP 618	Advanced Sensors

- ✓ **# This is an audit course which is mandatory for both the semesters of this programme students.**
- ✓ **Evaluation Process: This is a seminar course where specialists will give talk(s) on various verticals like: biology, healthcare, retail governance, physical sciences, e-commerce, climate, supply chains and financial services, manufacturing, hospitality etc. This seminar series will provide the industry or domain specific context for advanced analytics. Summary report of each presentation of the talk given by the expert will be submitted by each student. In addition to this, at the end of the presentation of the expert talk, an exam will be conducted for 10 marks of each talk and a question paper will be set by the expert who has given the talk given to the students. Students will also explore the journal papers, do literature Survey related to this course and give at least one presentations in a month. A total of minimum of 5 presentations by expert talk and each student by 5 talks will be evaluated. A total of 100 marks evaluation will be done to assess the student in this course.**

Course Code	**AM 603D**
Course Name	**Computer Oriented Optimization Techniques**
L – T – P - C	**03 – 01 - 0 – 4 / 03 – 0 - 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

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

CO1: understand the application of various optimization techniques that can help to make decisions for practical problems in industries and apply basic concepts of mathematics to formulate an optimization problem.

CO2: understand the importance of optimization of industrial process management with the theory of optimization methods and algorithms developed for solving various types of optimization problems.

CO3: analyze and appreciate the variety of performance measures for various optimization problems such as Sensitivity analysis, Risk analysis and Portfolio Management, etc.

CO4: implement, develop and promote research interest in applying optimization techniques in problems of Engineering and Technology. And the mathematical results and numerical techniques of optimization theory to concrete Engineering problems.

Course Contents

Linear programming: Simplex method, Two-phase method, Big-M method, duality, Integer linear Programming, Dynamic Programming, Sensitivity analysis.

Assignment problem: Hungarian's algorithm, Degeneracy, applications, unbalanced problems, traveling salesman problem.

Classical optimization techniques: Single variable optimization with and without constraints, multi – variable optimization without constraints, multi – variable optimization with constraints – method of Penalty methods Lagrange multipliers, Kuhn-Tucker conditions.
Numerical methods for optimization: Minimization and maximization of convex functions- Local & Global optimum- Convergence-Speed of convergence. Nelder Mead's Simplex search method.
Constrained optimization: Constrained optimization with equality and inequality constraints. Kelley's convex cutting plane algorithm - Gradient projection method - Penalty Function methods. Constrained optimization: Lagrangian method - Sufficiency conditions - Kuhn-Tucker optimality conditions- Rate of convergence - Engineering applications Quadratic programming problems-Convex programming problems.
Unconstrained optimization: One dimensional minimization - Elimination methods: Fibonacci & Golden section search - Gradient methods - Steepest descent method
Genetic algorithm (GA) : Differences and similarities between conventional and evolutionary algorithms, working principle, reproduction, crossover, mutation, termination criteria, different reproduction and crossover operators, GA for constrained optimization, draw backs of GA
Genetic Programming (GP): Principles of genetic programming, terminal sets, functional sets, differences between GA & GP, random population generation, solving differential equations using GP.

Texts / References

Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
Engineering Optimization: Theory and Practice, 4th Ed., 2009, S.S. Rao, Wieley Eastern Ltd.
Optimization: Theory and Practice, 2004, MC Joshi, KM Moudgalya, Narosa.
Introduction to Optimization, 1988, Beale, John Wiley.
Optimization for Engineering Design – Kalyanmoy Deb, PHI Publishers
Genetic algorithms in Search, Optimization, and Machine learning – D.E.Goldberg, Addison Wesley Publishers
Genetic programming: on the programming of computers by means of natural selection- John R. Koza, MIT Press, 1992.
Genetic Programming Theory and Practice by Rick Riolo, Bill Worzel, Kluwer Academic Publishers
Genetic Programming: An Introduction, Wolfgang Banzhaf, Peter Nordin, Robert E. Keller, Frank D. Francone, Morgan Kaufmann Publishers
. **Multi objective Genetic algorithms - Kalyanmoy Deb, PHI Publisher**
. **Numerical Methods and Optimization, Hari Arora, S.K. Kataria& Sons**
. **Numerical Methods and Optimization: A Consumer Guide, Eric Walter, Springer**
. **David G Luenberger, .Linear and Non Linear Programming., 2nd Ed, Addison-Wesley.**
. **Bazarra M.S., Sherali H.D. & Shetty C.M., Nonlinear Programming Theory and Algorithms, John Wiley, New York, 1979.**

Course Code	**AM 604D**
Course Name	**Statistical Computing for Data Science**
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

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

CO1: understand the fundamental concepts of probability and statistics such as Axioms, addition law, conditional probability, Baye's principle etc., and their real-life application to predict the data.
CO2: understand the importance of Probability Distributions such as Binomial, Poisson, Normal and Exponential Distributions and their properties and problems on special probability distributions.
CO3: analyze and appreciate the statistical theory behind Curve fitting, regression modeling and Chi Square Test, student test & Fisherman test.
CO4: understand the theory behind Design and Analysis of Experiments: Need for conducting Experiments, and their possible applications.

Course Contents

Probability Theory: Sample Spaces- Events - Axioms – Counting - Conditional Probability and Bayes' Theorem – The Binomial Theorem – Random variable and distributions : Mean and Variance of a Random variable-Binomial-Poisson-Exponential and Normal distributions. Curve Fitting and Principles of Least Squares- Regression and correlation.
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.
Tabular data- Power and the computation of sample size- Advanced data handling Multiple regression- Linear models- Logistic regression- Rates and Poisson regression Nonlinear curve fitting. **Density Estimation**- Recursive Partitioning- Smoothers and Generalised Additive Models - Survivals Analysis- Analysing Longitudinal Data- Simultaneous Inference and Multiple Comparisons- Meta-Analysis- Principal Component Analysis- Multidimensional Scaling Cluster Analysis.
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.

Texts / References

Stochastic Process, 3rd Ed., 2010, J. Medhi, New Age Science Ltd.
Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
All of Statistics: A Concise Course in Statistical Inference, 2003, Larry Wasserman, Springer.
Introduction to Statistical Modelling, 2010, W. J. Krzanowski, Oxford university press.
Schaum's outlines Probability and statistics, 4th Ed., 2013, Murray R. Speigel, John Schiller, R Alu Srinivasan, Tata McGraw Hill
Richard Cotton, "Learning R", O'Reilly, 2013.
Dalgaard, Peter, "Introductory statistics with R", Springer Science & Business Media, 2008.
Brain S. Everitt, "A Handbook of Statistical Analysis Using R", Second Edition LLC, 2014.
. Samir Madhavan, "Mastering Python for Data Science", Packt, 2015.
. Sheldon M. Ross,"Introduction to Probability and Statistics for Engineers and Scientists", 4th edition, Academic Press; 2009.
. Paul Teetor, "R Cookbook, O'Reilly, 2011.
. Mark Lutz ,"Learning Python", O'Reilly,5th Edition,2013

Course Code	**AM 606D**

Course Name	**Scientific Computing**
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

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

CO1: Solve systems of linear equations.
CO2: Find roots of mathematical functions.
CO3: Numerically solve SVD problems.
CO4: Find optimum solutions to numerical problems.
CO5: Explain the mathematical basis of the above techniques.

Course Contents

Definition and sources of errors, solutions of nonlinear equations; Bisection method, Newton's method and its variants, fixed point iterations, convergence analysis; Newton's method for non-linear systems; Finite differences, polynomial interpolation; Numerical integration - Trapezoidal and Simpson's rules, Gaussian quadrature; Initial value problems - Taylor series method, Euler and modified Euler methods, Runge-Kutta methods.

Linear systems – All variants of Gaussian elimination and LU factorization, Cholesky factorization.

Linear least-squares problem - Normal equations, rotators and reflectors, QR factorization via rotators, reflectors and Gram Schmidt orthonormalisation, QR method for linear least-squares problems, rank deficient least-squares problems.

Singular value decomposition (SVD) – numerical rank determination via SVD, solution of least squares problems, Moore- Penrose inverse, low rank approximations via SVD, Principal Component Analysis, applications to data mining and image recognition.

Eigenvalue Decomposition - Power, inverse power and Rayleigh quotient iterations, Schur's decomposition,
unitary similarity transformation of Hermitian matrices to tridiagonal form, QR algorithm, implementation of
explicit QR algorithm for Hermitian matrices

Texts / References

L. N. Trefethen and David Bau, Numerical Linear Algebra, SIAM, Phildelphia, 1997.
D. S. Watkins, Fundamentals of Matrix Computation, 2nd Edition, Wiley, 2002.
L. Elden Matrix Methods in Data Mining and Pattern Recognition, SIAM, Philadelphia, 2007
D. Kincaid and W. Cheney, Numerical Mathematics and Computing, 7th Edn., Cengage, 2013.
K. E. Atkinson, Introduction to Numerical Analysis, 2nd Edn., John Wiley, 1989.
L. N. Trefethen and David Bau, Numerical Linear Algebra, SIAM, 1997.
D. S. Watkins, Fundamentals of Matrix Computation, 2nd Edn., Wiley, 2002.
D. Kincaid and W. Cheney, Numerical Analysis: Mathematics of Scientific Computing, 3rd Edn., AMS, 2002.
K. E. Atkinson, Introduction to Numerical Analysis, 2nd Edn., John Wiley, 1989.

Course Code	**AM 607D**
Course Name	**Data Structures and Algorithms with C**
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Outcomes: After completing this course, the students will be able to: CO1 learn the c 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 learn different sorting, searching, and shortest path finding algorithms and also do the complexity analysis of these algorithms CO4:gain coding expertise by taking up case studies in data structures and in algorithms.
Course Contents
Preliminaries: Concept & notation, common operation on data structures, algorithm complexity, time space trade-off between algorithm, physical & logical representation of different data structures. Arrays: Arrays defined, representing arrays in memory, Various operation (traversal, insertion, deletion), Multidimensional arrays, Sequential allocation, Address calculation, Sparse arrays. List: Simple Array Implementation of Lists, Linked Lists, Doubly Linked Lists, Circularly Linked list. Stack: Stack Model, Implementation of Stacks, Applications of Stacks. **Queue:** Queue Model, Array Implementation of Queues, Applications of Queues. Trees: Implementation Of Trees, Tree Traversal with an application, Binary Trees-Implementation, Expression trees, Binary Search Tree, Binary Search Trees, Various Operations On BST- Make Empty, Find, Find Min and Find Max, Insert, Delete, Average-Case Analysis, AVL Trees- Single Rotation , Double Rotation, B-trees. Hashing: Definition, Hash Function, Separate Chaining, Open Addressing- Linear Probing, Quadratic Probing, Double Hashing, Rehashing, Extendible Hashing. **Priority Queues**: Model, Simple Implementation, Binary Heap-Structure Property, Heap Order Property, Basic Heap Operation, Application Of Priority Queues- The Selection Problem, Event Simulation, Heap Sorting: Preliminaries, Insertion Sort- Algorithm, Analysis Of Insertion Sort, Shell sort- Analysis Of Shell sort, Heapsort- Analysis Of Heapsort, Merge sort- Analysis Of Merge sort, Quicksort- Picking the Pivot, Partitioning Strategy, Small Arrays, Analysis Of Quicksort , Bucket Sort. **Graphs:** Definitions, Representation Of Graphs, Topological Sort, Shortest Path Algorithms- Unweighted Shortest Paths, Dijkstra's Algorithm, Graph With Negative Edge Costs, Acyclic Graphs, All- Pairs Shortest, Minimal Spanning Tree- Prim's Algorithm, Kruskal's Algorithm, Application Of Depth First Search- Undirected Graphs, Biconnectivity, Euler Circuits, Directed Graphs. Algorithm Design Techniques: Greedy Algorithms- A Simple Scheduling Problem, Huffman Codes, Divide And Conquer Running Time Of Divide and Conquer Algorithms, Closets-Points Problem, The Selection Problem
Texts / References
Mullis Cooper: Spirit of C: Jacob Publications **YashwantKanetkar: Let us C: BPB** **Gotterfied B.: Programming in C: Tata McGraw Hill** **Jean Paul Tremblay & Paul G. Sorenson: An Introduction to Data Structures with Applications: Tata McGraw Hill.** **Robert L. Kruse: Data Structures & Program Design: PHI**

Course Code	**AM 609D**
Course Name	**Data Science: Industrial Perspectives**
L – T – P - C	**0-0- 0-2**
Offered as (Compulsory / Elective):	**Audit - Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING / AUTUMN**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Outcomes: After completing this course, the students will be able to: CO1:Acquire a fundamental understanding of the analytical techniques and software tools necessary to effectively generate useful information from structured and unstructured datasets of any size CO2:Gain experience in using the tools and techniques of data science to structure and complete projects focused on obtaining actionable insights from complex data CO3:Dive deeply into a chosen area of practice to fully prepare to use knowledge gained in the program to add significant value in a professional setting CO4:Be able to utilize knowledge and skills to continue learning and adapting to new data science technologies
Course Contents
This is a seminar course where specialists will give talk(s) on various verticals like: biology, health, governance, physical sciences, e-commerce, climate, supply chains and finance etc. This seminar series will provide the industry or domain specific context for advanced analytics. This will include the following topics: Industry/domain overview description, history, challenges faced, key players, industry trends. Key business processes (marketing, financial, sales, logistics, order fulfilment, procurement, executive reporting, customer facing). Key data elements for each major business process and systems of record. Critical metrics (KPI) for each business process and the definitions. Sources/location of the data, typical errors in data. Benchmarking information sources. Signal and noise in system information relevance. Classes of users and associated metrics/information needed/questions asked or would like to ask.. Potential for new apps. Historical access to information and impacts. Impact of social media, text analysis, web and other sources of information. Timeliness of data/information. Predictive Vs historical analysis (customer segmentation, churn etc).
Subject domains / industry
Politics/elections required reading http://fivethirtyeight.com/ Nate Silvers book (signal and the noise), invite party strategists from major parties. Crowd sourced analytics (www.kaggle.com). Healthcare invite CFO/CMO from AIIMS, Apollo and/or other large hospitals to discuss metrics for hospital operation including financial, operational and medical procedures efficacy. Supply chain management invite VP/Operations/Logistics from auto companies, Flipkart/Amazon to discuss supply chain analytics and issues. Weather/climate change National weather bureau chief. Agriculture Industry think tanks re crop yields, weather patterns, evolving trends. Corporate - HR, Finance, Sales, Marketing, Web marketing, IT. Customer services/ support. Website analytics - Google. Financial Services Chief Marketing Officers/CEO to discuss customer analytics, services, service quality, innovation, profitability. Energy prospecting ONGC, Chevron, BP. Security communications, RAW, National Security agencies. Entertainment - movie/show launches. Retail Hindustan Lever, Proctor & Gamble, Godrej. Telecom Airtel, BSNL, Vodafone Education Teach for India, UNICEF, Gates Foundation.

Course Code	**AM 623D**
Course Name	**Machine Learning**
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

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.

Course Contents

Introduction - Definitions – Theoretical- Definitions – Applied Practice- 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
Evaluation Hypotheses – Motivation, Estimation hypothesis accuracy, Basics of sampling theory, Ageneral approach for deriving confidence intervals, Difference in error of two hypotheses, Comparing learning algorithms
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, Gibbs algorithm, Naïve Bayes classifier, An example learning to classify text, Bayesian belief networks The EM algorithm.
Graphical and sequential models- Bayesian networks- conditional independence Markov random fields- inference in graphical models- Belief propagation- Markov models- Hidden Markov models- decoding states from observations- learning HMM parameters.
Computational learning theory – Introduction, Probability of 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 (Passive vs Active learning, V-C dimension). Clustering Methods-Partitioned based Clustering - K-means- K-medoids; Hierarchical
Clustering - Agglomerative- Divisive- Distance measures; Density based Clustering - DBScan; Spectral clustering.
Types of Machine Learning –Supervised –Unsupervised – Reinforcement-Decision Tree learning.
Neural networks- the perceptron algorithm- multilayer perceptron's- back propagation nonlinear regression- multiclass discrimination- training procedures- localized network structure - dimensionality reduction interpretation.

Texts / References

Tom M. Mitchell, Machine Learning –- MGH
Stephen Marsland , Machine Learning: An Algorithmic Perspective, Taylor & Francis (CRC)
William W Hsieh, , Machine Learning Methods in the Environmental Sciences, Neural Networks, Cambridge Univ Press.
Richard o. Duda, Peter E. Hart and David G. Stork, pattern classification, John Wiley & Sons Inc., 2001.
Chris Bishop, Neural Networks for Pattern Recognition, Oxford University Press, 1995

Charles Dierbach, Introduction to computer science using Python a computational problem solving focus, John-Wiley & Sons, 2012.
T. Hastie, R. Tibshirani and J. Friedman, “Elements of Statistical Learning”, Springer, 2009.
E. Alpaydin, “Machine Learning”, MIT Press, 2010.
K. Murphy, “Machine Learning: A Probabilistic Perspective”, MIT Press, 2012.
. C. Bishop, “Pattern Recognition and Machine Learning, Springer”, 2006.
. Shai Shalev - Shwartz, Shai Ben-David, “Understanding Machine Learning: From Theory to Algorithms”, Cambridge University Press, 2014.
. John Mueller and Luca Massaron, “Machine Learning For Dummies“, John Wiley & Sons, 2016.

Course Code	**AM 624D**
Course Name	**Data Science: Tools and Techniques**
L – T – P - C	**0-0- 0-2**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

Course Outcomes: After completing this course, the students will be able to:
CO1: Understand the fundamental concepts of data science and terminology.
CO2: Understand the fundamental concepts of data science process and machine learning concepts.
CO3: Understand the fundamental concepts of tools used in data science.
CO4: Fundamental concepts of large data & Data Visualization.
CO5: To implement the aspects of Data Science through case studies.

Programming Language: Introduction to Python, Programming Interfaces, Spyder, Python script file, Print Message to Standard Output, variables and data types, Reading Input from console, Type Conversion, Arithmetic Operators and Conditions

Control Flow - Relational Operators, if…else statement , if…else if…else statement, Logical operators, While Loops, break and continue statement, Loops with else statement, pass statement, Python for loop, Range Function, **Lists:** Creating List, Accessing elements from List, Inserting and Deleting Elements from List, List Slicing, Joining two list, Repeating sequence, Nested List, Built-in List Methods and Functions, Searching elements in List, Sorting elements of List

Python Data Structures: Python Set, Creating Set, Adding/Removing elements to/from set , Python Set Operations : Union, Intersection, Difference and Symmetric Difference, Python Tuple, Creating Tuple, Understanding Difference between Tuple and List, Accessing Elements in Tuple, Python Dictionary, Creating Dictionary, Accessing / Changing / Deleting Elements in Dictionary

Data Pre-processing Numpy and Pandas: 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

Pandas: Reading Files, Writing Files, Loading Data with Pandas, Selecting Specific Columns, Selecting rows using labels: loc, Selecting rows using position: iloc, Adding and Removing rows and Columns, Filtering Data Frames, Importing Data from csv Files, Missing Data Handling, OnHot Encoder, Label Encoding, Data Splitting, Training Data, Importance of Test Data.

Built-in Dictionary Methods and Functions: Data Analytics**,** Data preprocessing, Analyzing data, Handling missing data, Applying Machine learning techniques to analyze data

Functions: Defining Functions in Python, Function Argument, Single Parameter Functions, Function Returning single Values, Functions with multiple parameter, Function that return Multiple Values, Functions with Default arguments, Named arguments, Scope and Lifetime of Variables, Global specifier

Data Visulization With MatplotLib: Introduction to Matplotlib, Basic Plotting with Matplotlib, Line Plot on Example DataSet, Exploring the plot Options, Other types of Plots, Bar Plot, Pie Plot, Histograms

Regression for data analysis: Introduction to regression and Classification, Types of Classification, Simple Linear regression Intuition, Sci kit Learn Library, Hands on Lab on Simple Linear Regression, Performance Evaluation

Regression and Classification Part 2 : Multivariable Linear regression, Handson Example on Multivariable LR, Performance Evaluation, Improving the Performance, Backward Elimination method, Other types of Regression Models, Performance Evaluation of different Regression Models

Classification in Machine Learning : Classification Introduction, K-Nearest Neighbours, Decision Tress, Naïve Bayes algorithm, Support Vector Machine, Introducing Correlation Matrix

Deep Learning: Deep Learning Introduction, Deep learning methods, Supervised Deep learning, Unsupervised deep learning

Artificial Neural Networks(ANN): Introduction to ANN, Practical use cases of ANN, Understanding Neural Networks, Hidden Layers, Activation Functions-(Relu, Soft max), Feed forward and Backward Propagation, Introducing Keras and Tensor flow for Neural Network, Hands on Example on ANN to understand above concepts (defining the input layers, creating hidden layers, Activation function usage, Output Layer), Understanding the network training, Module loss, Validation loss calculation, Performance Improvement by introducing Dropout layer.

Deep Learning with Convolutional Neural Networks (CNN): Introduction to Convolution, Application of CNN, Different Layers in CNN, Convolution Kernel understanding, Activation functions in CNN, Relu, Softmax, Pooling Layer, Fully connected Layer, Deep Neural Network

CNN in Computer Vision application: Image Processing introduction, Types of Images, Importing and exporting images, Visualizing Images in Python, Image filtering, Data Augmentation, Hands-on Laboratory to understand CNN better"Tagging Images into different labels", Padding in CNN, Batch Normalization, Confusion Matrix, Mini project Building CNN model to recognize the handwritten digit, Saving the Models, Using Pre-trained Models, Recurrent Neural Networks.

Samir Madhavan, Mastering Python for Data Science, Packt Publishing, 2015
Sebastian Raschka Python Machine Learning, Packt Publishing, 2015
H. Bhasin, Python Basics, Mercury Learning And Information, 2019
Magnus Lie Hetland, Beginning Python, Apress, 2015
Nikhil Ketkar, Deep Learning withPython, Apress, 2017
Peter Norton, Alex Samuel, David Aitel, Eric Foster-Johnson, Leonard Richardson, Jason Diamond, Aleatha Parker, Michael Roberts Beginning Python, Wiley Publishing, 2005
Expert Python Programming: Best practices for designing, coding, and distributing your Python software Tarek Ziadé, Packt Publishing, 2008.
Programming Python, Mark Lutz, O'Reilly Media, 2010.
Programming in Python 3: A Complete Introduction to the Python Language, Mark Summerfield, Addison-Wesley, 2010
Practical programming: An introduction to computer science using Python, Jennifer Campbell, Paul Gries, Jason Montojo, Greg Wilson, Pragmatic Bookshelf, 2009.
Core Python Programming, 2nd Edition, Wesley Chun, Prentice Hall, 2006.
Core Python Applications Programming, Wesley J Chun, Prentice Hall, 2012
Programming Computer Vision with Python: Tools and algorithms for analyzing images, Jan Erik Solem, O'Reilly Media, 2012
Convolutional Neural Networks in Python, Lazy Programmer. Kindle Edition

. Neural Network Projects with Python, James Loy, Packt Publishing

Course Code	**AM 625D**	
Course Name	**Image and Video Analytics**	
L – T – P - C	**03 – 01 - 0 - 4 / 03 – 0- 2 - 4**	
Offered as (Compulsory / Elective):		**Elective**
Offered in (SPRING / AUTUMN)		**SPRING**
Offered by (Name of Department/ Centre)		**Applied Mathematics**

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

CO1: understand basic image model, and will learn basic image processing techniques to analyze the image in terms of histogram, contrast, sharpness, etc.

CO2: learn different image enhancement techniques, and also understand the factors which degrades the quality of an image, and also learns the image restoration techniques. Different spatial filtering operations for image enhancement will be learnt along with the morphological operations.

CO3: learn image segmentation algorithms, understands the need for image compression and learn the spatial and frequency domain techniques used for image compression.

CO4: learn different feature extraction techniques employed for image analysis and recognition, and gets an overview on applications of image processing in Machine vision

Course Contents

Digital Image Fundamentals: Introduction – Origin –Steps in Digital Image Processing – Components; Elements of Visual Perception – Light and Electromagnetic Spectrum – Image Sensing and Acquisition – Image Sampling and Quantization – Relationships between pixels.

Image Enhancement: Spatial Domain: Gray level transformations – Histogram processing – Basics of Spatial Filtering–Smoothing and Sharpening Spatial Filtering – Frequency Domain: Introduction to Fourier Transform – Smoothing and Sharpening frequency domain filters – Ideal, Butterworth and Gaussian filters.

Image Restoration: Noise models – Mean filters – Order Statistics – Adaptive filters – Band reject – Band pass – Notch – Optimum notch filtering – Inverse Filtering – Constrained Least Square Filtering – Wiener filtering.

Morphological image processing: Dilation, Erosion, Opening, Closing, Applications to; Boundary extraction, Region filling, Extraction of connected components.

Image Compression: Fundamentals – Image Compression models – Error Free Compression – Variable Length Coding –Bit – Plane Coding – Lossless Predictive Coding – Lossy Compression – Lossy Predictive Coding –Wavelet Coding – Compression Standards – JPEG2000.

Image Segmentation and Representation: Segmentation – Detection of Discontinuities – Edge Linking and Boundary detection – Region based segmentation; Representation – Boundary descriptors – Simple Descriptors – Shape numbers –Regional descriptors – Simple and Topological Descriptors – Introduction to Image Processing Toolbox – Practice of Image Processing Toolbox – Case studies– Various Image Processing Techniques. Object recognition: Decision-theoretic methods.

SVM, feature selection methods, feature extraction methods, Maximum Output Information (MOI) for joint selection and classifier training.

Colour models and Transformations – Image and Video segmentation - Image and video demonising- Image and Video enhancement- Image and Video compression. Object detection and recognition in image and video - Texture models Image and Video classification models- Object tracking in Video

Texts / References

Digital Image Processing, 3rd Ed., 2007, R. C. Gonzalez, Richard E. Woods, Prentice Hall.

Digital Image Processing Using MATLAB, 2nd Ed., 2009, R. C. Gonzalez, Richard E. Woods, Steven L. Eddins, Gatesmark Publishing.
Digital Picture Processing, 2nd Ed., 1982, A. Rosenfeld, A. C. Kak, Academic Press.
Fundamentals of Digital Image Processing, 1st Ed., 1989, A.K. Jain, Prentice Hall of India.
Pattern Classification and Scene Analysis, 1973, R. O. Duda, P. E. Hart, John Wiley.
Pattern Recognition, Applications to Large Data-Set Problems, 1984, Sing-Tze Bow, Marcel Dekker.
Rick Szelisk, "Computer Vision: Algorithms and Applications", Springer 2011.
Jean-Yves Dufour, "Intelligent Video Surveillance Systems", Wiley, 2013.
Caifeng Shan, Fatih Porikli, Tao Xiang, Shaogang Gong, "Video Analytics for Business Intelligence", Springer, 2012.

Course Code	**AM 627D**		
Course Name	**Information Theory and Coding**		
L – T – P - C	**03 – 01- 0 - 4**	**OR**	**03 – 0- 2 - 4**
Offered as (Compulsory / Elective):		**Elective**	
Offered in (SPRING / AUTUMN)		**AUTUMN**	
Offered by (Name of Department/ Centre)		**Applied Mathematics**	

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

CO1: learn the channel performance using Information theory.
CO2: Comprehend various error control code properties
CO3: Apply linear block codes for error detection and correction
CO4: Apply convolution codes for performance analysis & cyclic codes for error detection and correction.
CO5: Design BCH & RS codes for Channel performance improvement against burst errors.

Course Contents

Information Theory: Uncertainty, Information, Entropy, Discrete Memoryless Channel, Mutual Information, Channel Capacity, Shannon's Theorems, Gaussian Channel, Limits to Communication
Linear Block Codes: Groups, Fields and Vector Spaces, Construction of Galois Fields of Prime Order, Syndrome Error Detection, Standard Array and Syndrome Decoding, Hamming Codes
Cyclic Codes: Polynomial Representation of Code words, Generator Polynomial, Systematic Codes, Generator Matrix, Syndrome Calculation and Error Detection, Decoding of Cyclic Codes
Structure and Properties of Convolutional Codes: Convolutional Encoder Representation, Tree, Trellis, and State Diagrams, Distance Properties of Convolutional Codes, Punctured Convolutional Codes and Rate Compatible Schemes
Decoding of Convolutional Codes: Maximum Likelihood Detection, The Viterbi Algorithm
Automatic Repeat Request Strategies: Basic Techniques, Hybrid ARQ
Introduction to Cryptography: History. Overview of cryptography, Simple classical cryptosystems, Cryptanalysis
Perfect Secrecy: Information theoretic security**,** One time pad
Secret and Public Key Encryption: Description of DES, Description of AES (advanced encryption standard), Trapdoor Function, The RSA Algorithm

Texts / References

Jorge Castiñeira Moreira, Patrick Guy Farrell , Essentials of Error-Control Coding, **John Wiley, 2006. ISBN: 978-0-470-02920-6**
G. A. Jones and J. M. Jones, "Information and Coding Theory," Springer, ISBN 1-85233-622-6, 3rd Edition.
John F. Dooley, History of Cryptography and CryptanalysisCodes, Ciphers, and Their Algorithms, Springer, 2018, ISBN 978-3-319-90442-9
Maria Welleda Baldoni, Ciro Ciliberto, Giulia Maria Piacentini Cattaneo, Number Theory, Elementary Cryptography and Codes, Springer, 2009, ISBN 978-3-540-69199-0

Jorge Castiñeira Moreira, Patrick Guy Farrell, Essentials of Error-Control Coding, John Wiley & Sons Ltd, 2006, ISBN-13 978-0-470-02920-6
Hideki Imai, Essentials of Error-Control Coding Techniques, Academic Press, Inc., 1990, ISBN 0-12-370720-X
Dominic Welsh, Codes and Cryptography, Oxford Science Publications, 1988
T. M. Cover, J. A, Thomas, "Elements of information theory," WielyInterscience,2nd Edition, 2006
R. W. Hamming, "Coding and information theory," Prentice Hall Inc., 1980.
. **Robert M. Gray, Entropy and Information Theory, 2ndEdition, Springer, 2011, ISBN 978-1-4419-7969-8**

Course Code	**AM 628D**
Course Name	**Computational Number Theory and Cryptography**
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**Applied Mathematics**

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

CO1: learn computational methods in Algebra and Number Theory.

CO2: understand fundamental number-theoretic algorithms such as the Euclidean algorithm, the Chinese Remainder algorithm, binary powering, and algorithms for integer arithmetic.

CO3: understand the number-theoretic foundations of modern cryptography and the principles behind their security.

CO4: Understand the mathematical foundations for security of modern cryptography, asymmetric crypto-systems based on hard computational problems from Algebra and Number Theory.

CO5: apply fundamental algorithms for symmetric key and public-key cryptography.

Course Contents

Introduction: Introduction to Cryptosystems, Classical Ciphers, Cryptanalysis of Classical ciphers, LFSR based stream ciphers. Shannon's Theory, Diffie-Helman Key Exchange, Rabin Cryptosystem, Knapsack Ciphers, Digital Signature, Secret Sharing, ElGamal Cryptosystem

Number Theory:

Divisibility: Representations of Integers, Computer Operations with Integers, Complexity of Integer Operations, Divisibility, Prime Numbers, The Fundamental Theorem of Arithmetic, Sieve of Eratosthenes, The Distribution of Primes, Greatest Common Divisor, Euclidean Algorithm, Mersenne Numbers, Fermat Numbers, Perfect numbers

Congruence: Congruences, Congruence Applications, Linear Congruences, The Chinese Remainder Theorem, Theorems of Fermat and Euler- Fermat, Wilson's Theorem, Pseudo Primes, Carmichael Numbers, The Euler Phi-Function, The Sum and Number of Divisors, Quadratic Residue, Quadratic Reciprocity. Legendre and Jacobi Symbols, Computing Legendre symbols, Primitive Roots, Quadratic Reciprocity Law,

Inter Factorization and Primality Testing Algorithms: Complexity of Number Theoretic Algorithms, Fermat's Factorization, Kraitchik's Improvement, Trial division, Pollard Rho Algorithm, p-1 method, CFRAC method, quadratic sieve method, elliptic curve method. **Primality testing algorithms:** Fermat test, Miller-Rabin test, Solovay-Strassen test, AKS test.

Computing discrete logarithms over finite fields: Baby-step-giant-step method, Pollard rho method, Pohlig-Hellman method, index calculus methods, linear sieve method, Coppersmith's algorithm.

Representation of finite fields: Groups, Fields, Finite Fields, Arithmetic in Finite Field, Finding Multiplicative Inverses in finite fields, Prime and extension fields, representation of extension fields, polynomial basis, primitive elements, normal basis, optimal normal basis, irreducible polynomials. Binary Fields and their application in Cryptosystems.

Elliptic Curve Cryptography: Introduction to Elliptic Curves, The elliptic curve group, elliptic curves over finite fields, Schoof's point counting algorithm, Discrete Log problem for Elliptic curves, Factorization using Elliptic Curve, Advantage of Elliptic Curve Cryptography over other Public Key Cryptosystems.

Texts / References

. J. Katz and Y. Lindell, Introduction to Modern Cryptography, 2nd Edition, Chapman & Hall/CRC, 2008

. Abhijit Das, Computational number theory, Chapman and Hall/CRC., 2018

. N. Koblitz, A Course in Number Theory and Cryptography, Springer 2006.

. I. Niven, H.S. Zuckerman, H.L. Montgomery, An Introduction to theory of numbers, John Wiley & Sons, Inc 2006.

. L. C. Washington, Elliptic curves: number theory and cryptography, Chapman & Hall/CRC, 2003.

. J. Silverman and J. Tate, Rational Points on Elliptic Curves, Springer-Verlag, 2005.

. D. Hankerson, A. Menezes and S. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag, 2004.

. J. Pipher, J. Hoffstein and J. H. Silverman , An Introduction to Mathematical Cryptography, Springer-Verlag, 2008.

. G.A. Jones and J.M. Jones, Elementary Number Theory, Springer-Verlag, 1998.

. R.A. Mollin, An Introduction to Cryptography, Chapman & Hall, 2001.

. Song Y. Yan: Number Theory for Computing, Springer-Verlag, Second Edition,2002.

. T. H. Cormen, C. E. Leiserson, and R. L. Rivest: Introduction to Algorithms, Second Edition, Prentice Hall of India, 1994.

. K. Rosen: Elementary Theory of Numbers, Fifth Edition, Addison Wesley, 2004.

. D. M. Bressoud: Factorization and Primality Testing, Springer-Verlag, 1989.

. V. Shoup, A computational introduction to number theory and algebra, Cambridge University Press

. M. Mignotte, Mathematics for computer algebra, Springer-Verlag.

. I. Niven, H. S. Zuckerman and H. L. Montgomery, An introduction to the theory of numbers, John Wiley

. J. von zur Gathen and J. Gerhard, Modern computer algebra, Cambridge University Press.

. R. Lidl and H. Niederreiter, Introduction to finite fields and their applications, Cambridge University Press.

. A. J. Menezes, Applications of finite fields, Kluwer Academic Publishers

. J. H. Silverman and J. Tate, Rational points on elliptic curves, Springer International Edition.

. D. R. Hankerson, A. J. Menezes and S. A. Vanstone, Guide to elliptic curve cryptography, Springer-Verlag

. A. Das and C. E. Veni Madhavan, Public-key cryptography: Theory and practice, Pearson Education Asia

. H. Cohen, A course in computational algebraic number theory, Springer-Verlag

Course Code	**PGC-601**
Course Name	**Research Methodology and IPR**
L – T – P - C	**2 – 0- 0 – 2**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**AUTUMN**
Offered by (Name of Department/ Centre)	**PGC/All Departments DIAT**

Course Outcomes: After completing this course, the students will be able to:
CO1: Understanding the fundamentals of research and its methodology
CO2: Choose the appropriate research design and develop appropriate research hypothesis for a research project
CO3: Knowledge of manuscript preparation, patents and Intellectual property
CO4: Technology transfer and application of IPR in various domains.

Course Contents

Unit I: Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations
Unit II: Effective literature studies approaches, analysis Plagiarism, Research ethics,
Unit III Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and
assessment by a review committee
Unit IV Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.
Unit V Patent Rights: Scope of Patent Rights. Licensing and transfer of technology.
Patent information and databases. Geographical Indications
Unit VI New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

Texts / References

. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for
. science & engineering students'"
. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for
. beginners"
. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
. Mayall, "Industrial Design", McGraw Hill, 1992.
. Niebel, "Product Design", McGraw Hill, 1974.
. Asimov, "Introduction to Design", Prentice Hall, 1962.
. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Course Code	**PGC-602**
Course Name	**Audit Course**
L – T – P - C	**2 – 0- 0 – 0**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**PGC/All Departments DIAT**

Unit I: English for Research Paper Writing
Unit II: Disaster Management
Unit II: Sanskrit for Technical Knowledge
Unit IV: Value Education
Unit V: Constitution of India

Unit VI: Pedagogy Studies Unit VII: Stress Management by Yoga Unit VIII: Personality Development through Life Enlightenment Skills

Course Code	**CE 615A**
Course Name	**Intelligent Algorithms**
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Computer Science**

Course Contents

Basics: Data Structures, Abstract Data Types, Dictionaries, Parameters of Algorithms, Growth Functions, Asymptotic Notations & Complexity analysis, Complexity measures.
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
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
Algorithms for AI& Special Applications: Classic Algorithms, Light-Weight Algorithms & Techniques, Self-Organization & Fault-Tolerance Techniques, Nature Inspired Algorithms
Efficient Algorithms: Computations in Cyber Physical Systems CPS, CPS based parallel & distributed Algorithms, Quantum Computing, Concepts of Qubits, Quantum Algorithms, Quantum Search-Space optimization

Texts / References

T. H Cormen, C E Leiserson, R L Rivest And C Stein: Introduction To Algorithms, 2nd Edition, Prentice Hall Of India, 2009.
Ellis Horowitz, Sartajsahni, S. Rajasekharan: Fundamentals Of Computer Algorithms, University Press, 2007.
Kenneth A. Berman, Jerome L. Paul: Algorithms, Cengag Elearning, 2002.
R. Sedgewick, "Algorithms In C++: Fundamentals, Data Structures, Sorting, Searching, Parts 1-4(English) 3rdedition, Pearson.
Recommended Research Papers During Instruction

Course Code	**CE 631**
Course Name	**Deep Learning**
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Elective**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Computer Science**

Course Contents

Unit I: Introduction : Overview of machine learning, linear classifiers, loss functions
Unit II: Optimization : Stochastic gradient descent and contemporary variants, back-propagation
Unit III: Feedforward networks and training : Activation functions, initialization, regularization, batch normalization, model selection, ensembles
Unit IV: Convolutional neural networks : Fundamentals, architectures, pooling, visualization
Unit V: Deep learning for spatial localization : Transposed convolution, efficient pooling, object detection, semantic segmentation
Unit VI: 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 VII: Deep generative models** : Auto-encoders, variational auto-encoders, generative adversarial networks, autoregressive models, generative image models, unsupervised and selfsupervised representation learning **Unit VIII: Deep reinforcement learning** : Policy gradient methods, Q-Learning : Project presentations
Texts / References
Goodfellow, Y. Bengio, A. Courville, Deep Learning, MIT Press, 2016. http://www. deeplearningbook.org. **K. P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012.** **C. M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006**.

Course Code	**CE 632**	
Course Name	**Computer Vision**	
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**	
Offered as (Compulsory / Elective):		**Elective**
Offered in (SPRING / AUTUMN)		**SPRING**
Offered by (Name of Department/ Centre)		**Computer Science**
Course Contents		
UNIT I IMAGE PROCESSING FOUNDATIONS: Review of image processing techniques – classical filtering operations – thresholding techniques – edge detection techniques – corner and interest point detection – mathematical morphology – texture **UNIT II SHAPES AND REGIONS**: Binary shape analysis – connectedness – object labeling and counting – size filtering – distance functions – skeletons and thinning – deformable shape analysis – boundary tracking procedures – active contours – shape models and shape recognition – centroidal profiles – handling occlusion – boundary length measures – boundary descriptors – chain codes – Fourier descriptors – region descriptors – moments **UNIT III HOUGH TRANSFORM**: Line detection – Hough Transform (HT) for line detection – foot-of-normal method – line localization – line fitting – RANSAC for straight line detection – HT based circular object detection – accurate center location – speed problem – ellipse detection – Case study: Human Iris location – hole detection – generalized Hough Transform (GHT) – spatial matched filtering – GHT for ellipse detection – object location – GHT for feature collation **UNIT IV APPLICATIONS**: Application: Face detection – Face recognition – Eigen faces – Application: Surveillance – foreground-background separation – particle filters – Chamfer matching, tracking, and occlusion – combining views from multiple cameras – human gait analysis Application: In-vehicle vision system: locating roadway – road markings – identifying road signs – locating pedestrians		
Texts / References		
E. R. Davies, “Computer & Machine Vision”, Fourth Edition, Academic Press, 2012. R. Szeliski, “Computer Vision: Algorithms and Applications”, Springer 2011. Simon J. D. Prince, “Computer Vision: Models, Learning, and Inference”, Cambridge University Press, 2012. Mark Nixon and Alberto S. Aquado, “Feature Extraction & Image Processing for Computer Vision”, Third Edition, Academic Press, 2012. D. L. Baggio et al., “Mastering OpenCV with Practical Computer Vision Projects”, Packt Publishing, 2012. Jan Erik Solem, “Programming Computer Vision with Python: Tools and algorithms for analyzing images”, O'Reilly Media, 2012.		

Course Code	**CE 694**

Course Name	**Big Data Analysis & Algorithms**
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Computer Science**

Course Contents

Unit I : Introduction to big data analysis: Evolution of data, data streams, structured & unstructured data, database models, graph data, normalizations

Unit II: Big data analytics platforms: Architectures, Frameworks that enable big data analytics

Unit III: Big data analytics storage & processing: Data Preprocessing, , Multi-Dimensional Data Models, Data Warehousing OLTPS, OLAPS, Data Warehouse Architectures, Datacube Computations, Big Data Mining Frequent Patterns, Big Data Associations & Correlations, Classifications & Predictions, Clustering Techniques & Analysis, Mining Data Streams, Graph Mining Mining Spatial & Temporal Objects, Predictive Analysis, Ad Hoc Queries, Web Analytics

Unit IV: Algorithms for massive data sets, Algorithms for SISD, SIMD environments, Linked Big Data Analysis – Graph Computing and Network Science, Big Data Visualization, Big Data Mobile Applications, Large-Scale Machine Learning, Big Data Analytics on Specific Processors, Hardware and Cluster Platforms for Big Data Analytics, Big Data Next Challenges – IoT, Cognition, and Beyond

Unit V: Big data analytics tools

Texts / References

Big Data Fundamentals: Concepts, Drivers & Techniques 2016 by Thomas Erl, Wajid Khattak, Paul Buhler, Publisher: Prentice Hall, 2016), Service Tech Press
Data Mining, Jiawei Han & Micheline Kamber, 2nd edition, Elsevier, 2006
Introduction To Algorithms, Thomas H. Cormen, Charles E. Leiserson, Ronaldo L. Rivest, Clifford Stien 2nd Edition
Research Papers discussed in the classroom discussions.
https://iveybusinessjournal.com/publication/why-big-data-is-the-new-competitive-advantage/
https://www.datameer.com/company/datameer-blog/challenges-to-cyber-security-and-how-big-data-analytics-can-help/
https://www.iss.nus.edu.sg/executive-education/discipline/detail/analytics-and-intelligent-systems

Course Code	**CE696**
Course Name	**Artificial Intelligence & Decision Support Systems**
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**
Offered as (Compulsory / Elective):	**Compulsory**
Offered in (SPRING / AUTUMN)	**SPRING**
Offered by (Name of Department/ Centre)	**Computer Science**

Course Contents

Unit I: Introduction to AI, Decision Support Systems, Knowledge-based Intelligent Systems, Rule based Expert Systems;

Unit II: Uncertainty Management in rule-based expert systems: Introduction to Uncertainty, Basic Probability Theory, Bayesian reasoning, Certainty Factors;191

Unit III: Learning: Overview of different forms of learning, Artificial Neural Networks: Basics of Neuron, Perceptron, Multi-layer neural networks, Back Propagation Algorithm;

Unit IV: Decision Support and Business Intelligence: Decision Support Systems and Business Intelligence, Decision Making Systems, Modeling, and Support, Knowledge Engineering and Data Mining: KDD Process, Pattern Recognition Systems, and Applications of Data Mining in Intelligent Systems.

Unit V: Fuzzy Expert Systems: Introduction to Fuzzy thinking, Linguistics variables and Hedges, Fuzzy Rules, Fuzzy Inference, Defuzification.

Texts / References

Stuart Russell & Peter Norvig, Artificial Intelligence: A Modern Approach, Prentice-Hall, Third Edition (2009) **E. Rich and K. Knight, Artificial Intelligence, 2nd ed., McGraw-Hill, New York, 1991.** **M. Ginsberg, Essentials of Artificial Intelligence, Morgan Kaufmann, San Mateo, Ca., 1993.** **D. Poole and A. Mackworth, Artificial Intelligence: Foundations of Computational Agents, Cambridge University Press, Cambridge, UK, 2010.** **P. H. Winston, Artificial Intelligence, 3rd ed., Addison-Wesley, Reading, Mass., 1992.** **Efraim Turban, Jay E. Aronson (2008), Ting-Peng Liang, Ramesh Sharda, "Decision Support and Business Intelligence Systems" 8th Edition, Pearson-Prentice Hall.** **Micheal Negnivitsky, Artificial Intelligence: A Guide to Intelligent Systems, Addison-Wesley, 3nd Edition, 2011** **Clyde W. Holsapple, Andrew B. Whinston (2010), "Decision Support Systems-A Knowledge-Based Approach", West Pub. Co.**

Course Code	**CE 699**	
Course Name	**Internet of Things**	
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**	
Offered as (Compulsory / Elective):		**Compulsory**
Offered in (SPRING / AUTUMN)		**SPRING**
Offered by (Name of Department/ Centre)		**Computer Science**
Course Contents		
Unit I Introduction to Internet of Things, Definition and Characteristics of IoT, Physical Design of IoT, IoT Protocols, IoT communication models, IoT Communication APIs Unit II 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 & Cloud offerings, Software environments, NEO, Security Inference, Defuzification.		
Texts / References		
"Internet of Things: A Hands-on Approach", by ArshdeepBahga and Vijay Madisetti (Universities Press), 2014 "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by Pethuru Raj and Anupama C. Raman (CRC Press) "Designing the internet of things", McEwen, Adrian, and Hakim Cassimally. John Wiley & Sons, 2013. Research Papers discussed in the classroom discussions		

Course Code	**EE 610D**	
Course Name	**MULTIRESOLUTIONAL SIGNAL PROCESSING**	
L – T – P - C	**03 – 01- 0 – 4 / 03 – 0- 2 - 4**	
Offered as (Compulsory / Elective):		**Compulsory**
Offered in (SPRING / AUTUMN)		**SPRING**
Offered by (Name of Department/ Centre)		**Electronics Engineering**

Course Contents
Introduction to Multiresolution Analysis: Vector Spaces – Properties– Dot Product – Basis – Dimension, Orthogonality and Orthonormality – Relationship Between Vectors and Signals – Signal Spaces – Concept of Convergence – Hilbert Spaces for Energy Signals- Fourier Theory: Fourier series expansion, Fourier transform, Short time Fourier transform, Time-frequency analysis, Definition of Multi Resolution Analysis (MRA) – Haar Basis – instruction of General Orthonormal MRA – Wavelet Basis for MRA – Continuous Time MRA Interpretation for the DTWT – Discrete Time MRA – Basis Functions for the DTWT – PRQMF Filter Banks. **Advanced DSP Techniques:** Matrix factorizations and least squares filtering, optimal linear filter theory, classical and modern spectral estimation, adaptive filters, and optimal processing of spatial arrays, Multirate signal processing, Multirate digital signal processing, Decimation, interpolation, sampling rate conversion, filter design and implementation for multirate conversion, sampling rate conversion by an arbitrary factor, applications of multirate signal processing. **Wavelet Transform Techniques:** Definition and Properties – Concept of Scale and its Relation with Frequency – Continuous Wavelet Transform (CWT) – Scaling Function and Wavelet Functions (Daubechies Coiflet, Mexican Hat, Sinc, Gaussian, Bi Orthogonal)– Tiling of Time – Scale Plane for CWT. DISCRETE WAVELET TRANSFORM Filter Bank and Sub Band Coding Principles – Wavelet Filters – Inverse DWT Computation by Filter Banks – Basic Properties of Filter Coefficients – Choice of Wavelet Function Coefficients – Derivations of Daubechies Wavelets – Mallat's Algorithm for DWT – Multi Band Wavelet Transforms Lifting Scheme- Wavelet Transform Using Polyphase Matrix Factorization – Geometrical Foundations of Lifting Scheme –Lifting Scheme in Z –Domain. **Advanced Transform Techniques for MSP:** Frequency for signal and image analysis, spatial frequency components, Signal/image restoration using the Fourier domain, Homomorphic filtering, Heisenberg plane, Huff transform, Examples of the Windowed FT, Gabor Transform in Heisenberg space, ACT, DCT, Hilbert transform, PC: from signals to images, Fuzzy logic for signal/image/video processing, applications of MSP in machine learning, Machine Learning for Sensors and Signal Data. **MSP implementations in FPGA:** Digital Signal Processing Designing for FPGA Architectures, filter designs, IP implementations, real-time MSP architecture implementations, high-speed signal recording, handling and processing, MAC engine implementations, speech, image and video processing, Implementations of DSP hardware technologies, DSP arithmetics, FIR and IIR digital filters, Multirate signal processing, Fourier transforms, and Adaptive filters, hybrid designs.
Texts / References
Moon & Stirling, Mathematical Methods and Algorithms for Signal Processing, Prentice Hall, 2000. ISBN 9780201361865 (required) **Adaptive Filter Theory by Simon Haykin, Prentice Hall, 2002 Neural and Adaptive Systems by Jose Principe et al, Joh Wiley & Sons, 2000.** **Wavelets and Subband Coding by Martin Vetterli and JelenaKovacevic, Prentice Hall, 2007. Notes and papers** **Discrete-Time Signal Processing by A. V. Oppenheim and R. W. Schafer, 3rd Edition, 2014.** **Digital Signal Processing: A Computer-based Approach by S. K. Mitra, 4th Edition, 2013.** **Multirate Systems and Filter Banks by P. P. Vaidyanathan, 1st Edition, 1993 (1st Pearson Impression in 2006).** **http://firasaboulatif.free.fr/index_files/gaidaa%20book/Digital%20Signal%20Processing/Multirate%20Filtering.pdf** **http://www.doiserbia.nb.rs/img/doi/0353-3670/2007/0353-36700703437R.pdf** **https://reality.ai/machine-learning-for-sensors-and-signal-data/** **. https://freevideolectures.com/course/3042/advanced-digital-signal-processing**

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	Sensors and Actuators -I	3	1	4
2	AP-607	Sensors and Actuators -II	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	Audit 1 and 2	0	0	0
		Total	**18**	**6**	**24**

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP-681	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-682	M.Tech. Dissertation Phase II	28		14
		Total	**28**		**14**

List of Electives:

Sr. No.	Course Code	Course
Elective I& II		
1	AP 610	Advanced Sensors
2	AP 611	Sensors for Defence
3	AP 612	Nanotechnology for Advanced Sensors
4	AP 651	Broadband Communication Systems
5	AP642	THz Devices and Applications
6	EE614	EMI, EMC, EMP, NEMP design
7	EE613	Electronic warfare
8	CE691	Wireless sensor network

AP-601 - Principles of Sensing: Material Science and Physics

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

Syllabus:

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

References Textbooks:

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)
4. Transducers and Instrumentation, DVS Murty, 2nd Edition2013
5. Material Science and Engineering by V.Raghavan
6. J. P. Dakin and B Culshaw, Optical Fiber Sensors, Vol. 1 & 2, Artech House, Boston and London,1998.

AP-602 – Sensor Data Acquisition Systems

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

Syllabus:

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

References Textbooks:

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. 3. Robert H King, "Introduction to Data Acquisition with LabVIEW", McGraw Hill, 2nd ed.,2012.
4. 4. John Park and Steve Mackay, Practical Data Acquisition for Instrumentation and Control', Newness publishers,2003.
5. 5. Maurizio Di Paolo Emilio, Data Acquisition systemss- from fundamentals to Applied Design, Springer,2013. 6. Robert H King

AP-603 – Technology and Packaging of MEMS systems

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

Syllabus:

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,	**8**

	Thermal Sensors. MEMS with Microactuators: Microgripper, Micromotors, Micro valves, Micro pumps, Micro accelerometer Microfluidics	
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

References Textbooks:

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

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)

AP-604 – Programming for Machine learning

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

Syllabus:

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

References Textbooks:

1. Introduction to Computation and Programming Using Python, by John V Guttag, MIT Press

EE-624 – DIGITAL SYSTEM DESIGN USING FPGAs

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

Syllabus:

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 - 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.	6
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..	6
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	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 Analyzers - Audio codec (AC97) interface – Test-bench design - ChipScope 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 Analyzers.

REFERENCE 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 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

AP-605 – Sensor Technology Laboratory-I

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

Syllabus:

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

AP-606 –Sensors and Actuators - I

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

Syllabus:

Units Divisions	Syllabus Details	Hrs
Unit I	Mechanical and electromechanical sensors: Resistive potentiometer, strain gauge, inductive sensor, capacitive sensor	10
Unit II	Magnetic sensors: Magneto-resistive, Hall effect sensors, Inductance and eddy current sensors, LVDT, RVDT	6
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.	12
Unit IV	Force and torque measurement: helical spiral springs, cantilever, beams, diaphragm, load cell, torsion bar, flat spiral spring for torque	6
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.	12

References Textbooks:

Texts/References

1. Sensors and signal conditioning by Ramon Pallas Arrny and John G Webster, John Wiley & sons (1991).
2. Handbook of Modern Sensors: physics, designs and applications by Jacob Fraden, Springer (2010).

3. Sensor Technology Handbook by John S Wilson, Elsevier, (2005) 4. Transducers and Instrumentation, DVS Murty, 2nd Edition 2013 5. Sensor Materials by P T Moseleyand A J Crocker
6. Material Science and Enginerring by V. Raghavan.

7. Fundamentals of Material Science and Enginerring by William D. Callister. 8. Principles of Materials Science & Engineering by W. F. Smith.

AP-607– Sensors and Actuators - II

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

Syllabus:

Units	**Syllabus Details**	**Hrs**
Unit I:	Optical properties, components, sources and detectors: types of sources : source- detector characterstics, 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

References Textbooks:

1] Handbook of Modern Sensors: Physics, Designs and Applications, Jacob Fradden, Third Edition, Springer

2] Micromachined Transducers Sourcebook," G.T.A. Kovacs,McGraw Hill,1998.

3] Actuators basics and applications, H Janocha,Springer.

4] Sensors and Transducers, D Patranabis PHI Publications, 2nd edition(2013).

AP-608 – Machine Learning techniques for Sensor Data Analytics

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

Syllabus:

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, hierarchial clustering	10
Unit V	Machine Learning issues: Overfitting, Validation, Occam's razor, Agglomerative Sampling bias, Data Snooping	10

References Textbooks:

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.
4. Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer,2006.
5. Y. S. Abu-Mostafa, M. Magdon-Ismail, and Hsuan-Tien Lin, Learning from data,AMLbook.com
6. Y. S. Abu-Mostafa, Learning from data, Caltech lectures(online)
7. S. Sarkar, Introduction to Machine Learning, NPTEL course, IIT Kharagpur(online).

AP-609 – Sensor Technology Laboratory- II

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

Syllabus:

Units Divisions	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

AP-610 – Advanced Sensors

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

Syllabus:

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.	**8**
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, ModernTrends	**8**
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 CommercialBiosensor, Demonstration of NMR, PET MRI	**8**
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, Sensors in exhaust gastreatment	**8**
Unit V	**Metamaterial based sensors, 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, CBW sensors (remote operation or hand-held).	8

References Textbooks:

1. Medical Instrumentation; Application and Design; J. G. Webster, Editor, 4th Edition,2015, JohnWiley&Sons,Inc.;NewYork.
2. John Turner, Automotive Sensors, Momentum Press, 1st Edition,2009.
3. Automotive Sensors, BOSCH,2002
4. Techniques of Radiation Dosimetry by K. Mahesh1985
5. Nuclear Radiation Detectors, S.S. Kapoor, V. S. Ramamurthy1986
6. Handbook Of Chemical AndBiological Sensors R.F Taylor, Jerome S. Schultz, 1996 by CRCPress

AP-611 – Sensors for Defence

Course Outcomes:

CO-1 :	To make students understand the importance of sensors for various defence applications
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 :	

Syllabus:

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 communications, other applications such as pipeline gauges, ham radio, night vision), StarSensors	10
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

References Textbooks:

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 relevantfield.
3. Research papers : Wolf, S., J. Davis, and M. Nisenoff. "Superconducting extremely low frequency (ELF) magnetic field sensors for submarine communications." *IEEE Transactions on Communications* 22.4 (1974):549-554.

4. Constable, Steven, and Leonard J. Srnka. "An introduction to marine controlled-source electromagnetic methods for hydrocarbon exploration." *Geophysics* 72.2 (2007): WA3- WA12.
5. 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.
6. Staszewski, Wieslaw, ChrBoller, and Geoffrey R. Tomlinson, eds. *Health monitoring of aerospace structures: smart sensor technologies and signal processing*. John Wiley & Sons, 2004

AP-612– Nanotechnology for Advanced Sensors

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 nanostrucutures for sensors

Syllabus:

Units Divisions	**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 Waals attraction potential, Interactions between two particles: DLVO theory, Solvent and polymer, Interactions between polymer layers, Mixed steric and electric interactions	8
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 8microscopy (SEM), Transmission electron m8icroscopy (TEM), Scanning probe microscopy (SPM), Surface plasmon resonance	8

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 Nanosensors, Arrays of Nanomaterial-based Sensors, e-nose	8

References Textbooks:

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)
4. Ramsden Jeremy, Nanotechnology, an Introduction. Elsevier(2011).
5. Florinel-Gabriel Banica,Chemical Sensors and Biosensors: Fundamentals and Applications, John Wiley and Sons(2012)

PGC-601 – Research Methodology and IPR

Course Outcomes:

CO-1 :	Understanding the fundamentals of research and its methodology
CO-2 :	Choose the appropriate research design and develop appropriate 3 hypotheses for a research project
CO-3 :	Knowledge of manuscript preparation, patents and Intellectual property
CO-4 :	Technology transfer and application of IPR in various domains

Syllabus:

Units Divisions	Syllabus Details
Unit I:	Meaning of research problem, Sources of the research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of the research problem.Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations
Unit II:	Effective literature studies approach, analysis Plagiarism, Research ethics,
Unit III	Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and

	assessment by a review committee
Unit IV	Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process ofPatenting and Development: technological research, innovation, patenting, development.International Scenario: International cooperation on Intellectual Property. Procedure forgrants 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 developmentsin IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

References Textbooks:

11. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for
12. science & engineering students'"
13. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
14. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
15. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
16. Mayall, "Industrial Design", McGraw Hill, 1992.
17. Niebel, "Product Design", McGraw Hill, 1974.
18. Asimov, "Introduction to Design", Prentice Hall, 1962.
19. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.
20. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

PGC-602 – Audit I and II

Course Outcomes:

CO-1 :	
CO-2 :	
CO-3 :	
CO-4 :	

CO-5 :	

Syllabus:

Units Divisions	**Syllabus Details**
Unit I:	English for Research Paper Writing
Unit II:	Disaster Management
Unit III	Sanskrit for Technical Knowledge
Unit IV	Value Education
Unit V	Constitution of India
Unit VI	Pedagogy Studies
Unit VII	Stress Management by Yoga
Unit VIII	Personality Development through Life Enlightenment Skills

END OF THE COURSE CONTENT

M. Tech. in Optoelectronics and Communication Systems (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 Laser 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	Laser & Optical Communication 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	Laser & Optical Communication 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	Audit 1 and 2	2	0	0
		TOTAL	**17**	**9**	**24**

SEMESTER III

Sl. No.	Course Code	Course	Contact Hours /week		Credits
			L	T/P	
1	AP-681	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-682	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
7	AP 651	Broadband Communication Systems
8	AP 652	Advanced Optical Communication
9	AP 653	Optical Networks

AP-621 –

Fundamentals of Laser and Laser Systems

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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

References Textbooks:

1. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.
2. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
3. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988
4. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
5. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).

AP-622 – Optical Electronics

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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	**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.	**10**
Unit V	**Magneto-optics**: Principles, Faraday effect, Gyrotropic permittivity, Kerr rotation and Kerr ellipticity, Applications.	**6**

References Textbooks:

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)
4. S. Sugano, N. Kojima (Eds.), Magneto-Optics, Springer Series in Solid-State Sciences, Vol. 128, 2000.

5. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
6. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988.
7. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.

AP-623 – Introduction to Fiber Optics

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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**

References Textbooks:

1. A.K. Ghatak & K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press 1998

2. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008
3. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998
4. J.P. Dakin & B Culshaw, Optical Fiber Sensors, Vol. 1&2., Artech House 1998
5. K.T.V. Grattan & B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, 1988

AP-624 – Semiconductor Photonic devices

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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**

References Textbooks:

1. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).
2. G. Ghione, Semiconductor Devices for High-Speed Optoelectronics, Cambridge University Press (2009)
3. A. Yariv and P. Yeh, Photonics: Optical Electronics in Modern Communication, Oxford University Press (2007), 6th Ed., Ch.15-17.
4. G. Keiser, Optical Fiber Communications, McGraw-Hill Inc., 3rd Ed. (2000), Ch.4, 6.
5. J. Singh, Semiconductor Optoelectronics: Physics and Technology, McGraw-Hill Inc. (1995).
6. J. M. Senior, Optical Fiber Communication: Principles and Practice, Prentice Hall of India, 2nd Ed. (1994), Ch.6-8.
7. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007), Ch.16, 17, and 18.
8. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021).

AP-625 – Quantum mechanics for Engineers

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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 atoms: 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**

References Textbooks:

1. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing
2. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing
3. Quantum Mechanics by B H Bransden and C J Joachain Pearson Publishing
4. Zettili, Nouredine. "Quantum mechanics: concepts and applications." John Wiley and Sons, Ltd., Publishing 2nd Ed. (2009).

AP-631 – Laser 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

Syllabus:

Units	Syllabus Details	Hours
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-	**12**

	induced fluorescence (LIF), Tunable diode laser spectroscopy (TDLS), Terahertz spectroscopy, Photoacoustic spectroscopy, Instrumentation in laser spectroscopy, Isotope Separation & Enrichment. Bio-Medical Application of Lasers	
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**

References Textbooks:

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
4. K. Bharat, Laser Safety Tools and Training, CRC Press 2009
5. K. Nagothu, New Paradigms for Underwater Communication, ProQuest 2009

AP-632 – Computational Photonics

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

Syllabus:

Units Divisions	**Syllabus Details**	**Hours**
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 Modeling:** Simulation and modeling of single mode and multimode optical fiber using mode solver, FBG and Chirped FBG synthesis, photonic crystal fiber simulation	**9**
Unit V	**Nanodesign:** Mask designing for nanofabrication of different device geometry	**6**

References Textbooks:

1. S. Sujecki, Photonics Modelling and Design, CRC Press, 2015.
2. K. Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2000.
3. A. Taflove, Computational Electrodynamics: The Finite-Difference Time Domain Method. Norwood, MA: Artech House, 1995.

AP-641 – High Power Lasers

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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,	**12**

	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 .	

References Textbooks:

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.
5. B. Zohuri, Directed Energy Weapons Technologies, CRC Press, 1 ed., 2012.
6. V VApollonov, High-Power Optics: Lasers and Applications, Springer International Publishing, Switzerland, 2015
7. Alastair D. McAulay, MILITARY LASER TECHNOLOGY FOR DEFENSE: Technology for Revolutionizing 21st Century Warfare, John Wiley & Sons, Singapore, 2011

AP-642 – Terahertz Devices and Applications

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 technologyfor imaging, sensing and communications

Syllabus:

Units	Syllabus Details	Hours
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	**9**

	and design, Terahertz MMICs: Theory and design, Terahertz detectors based on photonics	
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, Space Communication, Cutting-edge terahertz technologies	**9**

References Textbooks:

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.
4. H.-J. Song, T. Nagatsuma, Handbook of Terahertz Technologies, Devices and applications, Pan Stanford Publishing Pte. Ltd., 2015.
5. D. Saeedkia, Handbook of Terahertz Technology for Imaging, Sensing and Communications, Woodhead Publishing, 2013.

AP-643 – Free Space Optical Communications

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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	**9**

	turbulence on laser beam propagation, Realization of atmospheric effects on OWC test beds	
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**

References Textbooks:

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
4. Morris Katzman, Laser Satellite Communications. Prentice Hall Inc 1991
5. Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, A.K. Jha

AP-644 – Nanophotonics

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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 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, Designing photonics crystal for application: A Mirror, A Waveguide and A Cavity.	**12**

References Textbooks:

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: Molding Light Flow of Light, Princeton University Press, 2008.
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

AP-645 – Nonlinear and Quantum Optics

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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**

References Textbooks:

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. Y. R. Shen, The Principles of Non-linear Optics, John Wiley & Sons, 2003
5. R. W. Boyd, Nonlinear Optics, Academic Press, 2008.
6. H.M. Moya-Cessa and F. Soto-Eguibar, Introduction to Quantum Optics (Rinton Press 2011).
7. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, 2nd ed..John Wiley, 2007.
8. A. M. Weiner, Ultrafast Optics, Wiley Books, 2008
9. Gerry, Christopher; Knight, Peter, Introduction to Quantum Optics. Cambridge University Press, 2004.
10. L. Mandel, E. Wolf, Optical Coherence and Quantum Optics (Cambridge 1995).
11. D. F. Walls and G. J. Milburn, Quantum Optics (Springer 1994).

AP-646 – Integrated Optics and Silicon Photonics

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

Syllabus:

Units Divisions	**Syllabus Details**	**Hours**

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 andacousto-optic waveguide devices. Directional couplers, optical switch; phase andamplitude 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, MachZehnder 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**

References Textbooks:

1. William S. C. Chang, Fundamentals of Guided-wave optoelectronics devices, Cambrige 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.
5. H. Nishihara, M. Haruna, and T. Suhara "Optical Integrated Circuits", McGraw-Hill, 1988.
6. K Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2005.
7. *Ghatak* .A.K., and K. *Thyagarajan* ,Optical Electronics, Cambridge, 1989.

AP-651 – Broadband Communication Systems

Course Outcomes:

CO-1	Familiarize to the concepts of Communication technology
CO-2	Interpret the working principle of different types of conventional and Broadband technologies, in terms of signal modulation used
CO-3	Understand working of Cellular Communication systems
CO-4	Analyse the working of GSM Technology and complex modulation techniques used
CO-5	Summarize different applications from 4G to 6G Communication systems

Syllabus:

Units	Syllabus Details	Hours
Unit I:	Introduction to Basic Conventional Communication Systems – Modulation, Digital & Analog Communication systems. Introduction to Broadband Network Architectures, Concept of layered Models,OSI Layers and TCP/IP Models	**9**
Unit II	Basic Broadband Technologies: Internet Protocol Suite, IPv6, Basics of Intranet & Extranet technologies, X.25 Technology, Frame Relay, Frame Relay Standards, Types of VPN and General Architecture, Fiber Channel Technology & topologies.	**9**
Unit III	Cellular Communication: Analog Cellular Communications, The Cell site, The Mobile Telephone Switching Office (MTSO), Cell site Configurations, Tiered sites, Reuse of Frequencies, Allocation of Frequencies	**6**
Unit IV	Global Services Mobile Communications (GSM), Wireless Data Communication (Mobile IP) and GPRS: Analog to Digital Movement, GSM Architecture, Mobile Equipment (MS), BTS, BSC, BSS, MSC, VLR, IP Routing, Applications That Demand Mobile IP, Variations in Data Communications (Wireless), Possible Drawbacks with Wireless, Wireless Data Technology Options, The GSM Phase II Overlay Network, Circuit−Switched or Packet−Switched Traffic, GPRS Radio Technologies, PDP Contexts,	**9**
Unit V	Wireless Technology and Evolution of Modulation Technique – QAM, FDM, Orthogonal FDM, Adaptive Modulation Techniques. 4G & 5G:Introduction to 4G Standards, Introduction to 4G Architecture, components & basic internet & communication call flows. Introduction to 5G standards, basic 5G architectures, 5G services, Recent trends and applications in 5G, Massive Multiple-Input Multiple-Output (MIMO) Wireless Systems	**12**

References Textbooks:

1. Cajetan M. Akujuobi, Matthew N.O. Sadiku, Introduction to Broadband Communication Systems,Chapman and Hall/CRC, 2007.
2. Robert C. Newman, Broadband Communications Prentice Hall, NJ, USA, 2001.
3. Rajiv Ramaswami, Kumar N. Sivarajan and G. H. Sasaki, “Optical Networks: A Practical Perspective”, Elsevier, Third Edition, 2010.
4. B Sklar, “Digital Communications: Fundamentals and Applications” PH, 2001

5. Kuhn Paul J., Ulrich,Roya, “Broadband Communications” 1998.
6. SofoklisKyriazakos, River Publishers, 4G Mobile and Wireless Communications Technologies.
7. Jonathan Rodriguez, Wiley Publications, Fundamentals of 5G Mobile Networks

AP-652 – Advanced Optical Communication

Course Outcomes:

CO-1	Familiarize to the basics of Optical Communications
CO-2	Analyze the working principle of different types of Optical Components, Modules, and Subsystems
CO-3	Scrutinize the Advanced Modulation and Multiplexing Techniques
CO-4	Illustrate the practical implementation of Loss and Dispersion Management in Optical Fiber Communication
CO-5	Summarize different types of Nonlinear Effects in Fibers

Syllabus:

Units	Syllabus Details	Hours
Unit I:	**Basics of Optical Communications:** Model of Optical Communication, Signal Propagation Effects in Optical Fibers, Fiber Attenuation and Insertion Losses, Chromatic Dispersion Effects, Polarization-Mode Dispersion (PMD), Fiber Nonlinearities, Generalized Nonlinear Schrödinger Equation, Noise Sources in Optical Channels, Introduction to Quantum Communication	**9**
Unit II	**Optical Components, Modules, and Subsystems:** Key Optical Components, Optical Transmitters, Optical Receivers, Optical Signal-To-Noise Ratio, Receiver Sensitivity and Q Factor, Optical Amplifiers, Optical Couplers, Optical Filters, Optical Isolator, Optical Circulator, WDM Multiplexers and Demultiplexers, OFDM, Principles of Coherent Optical Detection, Coherent Optical Balanced Detectors	**9**
Unit III	**Advanced Modulation and Multiplexing Techniques:** Channel Capacity Theorem, Signal Space Theory, Pulse amplitude modulation (binary and M-ary, QAM), Pulse position modulation (binary and M-ary), Carrier modulation (M-ary ASK, PSK, FSK, DPSK), Continuous phase modulation (QPSK and variants, MSK, GMSK), Trellis Code Modulation, Probability of Error & Bit Error Rate, MIMO Fundamentals, Optical Time-Division Multiplexing, Subcarrier Multiplexing, Code-Division Multiplexing, Polarization-Division Multiplexing (PDM) and 4-D Signalling	**9**
Unit IV	**Loss and Dispersion Management:** Compensation of Fiber Losses, Role of Dispersive Effects, Periodically Amplified Lightwave Systems, Dispersion Problem in SMF, Dispersion-Compensating Fibers, Fiber Bragg Gratings, Dispersion-Equalizing Filters, Optical Phase Conjugation, Channels at High Bit Rates,	**9**
Unit V	**Nonlinear Effects in Fibers:** Origin of Linear and Nonlinear Refractive Indices, Second and Third Order nonlinearities, Self-phase modulation, Cross Phase modulation, Four-wave mixing, Combined	**9**

	Effect of Dispersion and SPM, Stimulated Raman scattering, Stimulated Brillouin scattering, Solitons communication systems.	

References Textbooks:

1. G. P. Agarwal, Fiber-Optic Communication Systems, 4th Ed., Wiley, 2010.
2. Advanced Electronic Communications Systems, by Wayne Tomasi, 6 Edition Pearson Education.
3. Kumar, Shiva, and M. Jamal Deen. Fiber optic communications: fundamentals and applications. John Wiley & Sons, 2014.
4. Djordjevic, Ivan B. Advanced optical and wireless communications systems. Heidelberg: Springer, 2018.

AP-653 – Optical Networks

Course Outcomes:

CO-1	Familiarize to the basics of Optical Networks
CO-2	Analyze the working principle of different WDM Network elements, its control and management
CO-3	Scrutinize the Advanced Modulation and Multiplexing Techniques
CO-4	Illustrate the practical implementation of Loss and Dispersion Management in Optical Fiber Communication
CO-5	Describe different FTTx Installation, Testing and Management

Syllabus:

Units	Syllabus Details	Hours
Unit I:	**Introduction to the Basics of Optical Networks:** Telecommunications Network Architecture, Services, Circuit Switching and Packet Switching, The Optical Layer, Transparency and All-Optical Networks, Optical Packet Switching, Transmission Basics, Network Evolution, SONET/SDH, Optical Transport Network, Generic Framing Procedure, Ethernet, IP, Multiprotocol Label Switching, Resilient Packet Ring, Storage-Area Networks	**9**
Unit II	**WDM Network elements, Control and Management:** Optical Line Terminals, Optical Line Amplifiers, Optical Add/Drop Multiplexers, Optical Crossconnects, Network Management Functions, Optical Layer Services and Interfacing, Layers within the Optical Layer, Multivendor Interoperability, Performance and Fault Management, Configuration Management, Optical Safety	**9**
Unit III	**Network Survivability and WDM Network Design:** Basic Concepts, Protection in SONET/SDH, Protection in the Client Layer, Why Optical Layer Protection, Optical Layer Protection Schemes, Interworking between Layers, Network Reliability and Security, Cost Trade-Offs: A Detailed Ring Network Example, LTD and RWA	**9**

	Problems, Dimensioning Wavelength-Routing Networks, Wavelength Conversion in WDM Network, Statistical Dimensioning Models, Traffic Grooming in Optical Networks.	
Unit IV	**Photonic Packet Switching and FTTx:** Optical Time Division Multiplexing, Synchronization, Header Processing, Buffering, Burst Switching, Testbeds, Introduction to FTTx, Fiber to the Home Architectures, FTTH in MDUs (Multiple Dwelling Units), FTTH PON Types, FTTH PON (Passive Optical Network), Triple Play Systems (BPON, GPON, EPON, RFOG) WDM and PON Other Uses for PONs, FTTX hardware and components (Cables, Splitters, Cabinets, Subscriber components).	**9**
Unit V	**FTTx Installation, Testing and Management:** Outdoor cable installation, Duct, aerial, direct burial, Micro-duct solutions, Drop cable installation, Fiber terminations on with pigtail, Splicing and joint closing, Testing FTTH (Key factors affecting network, Testing during construction, Testing for commissioning).	**9**

References Textbooks:

1. Rajiv Ramaswami, Kumar N. Sivarajan and G. H. Sasaki, "Optical Networks: A Practical Perspective", Elsevier, Third Edition, 2010.
2. P.E. Green, Jr., "Fiber Optic Networks", Prentice Hall, NJ, 1993.
3. C. Siva Ram Moorthy and Mohan Gurusamy, "WDM Optical Networks: Concept,Design and Algorithms", Prentice Hall of India, IstEdition, 2002.
4. Djordjevic, Ivan B. Advanced optical and wireless communications systems. Heidelberg: Springer, 2018.
5. Biswanath Mukherjee, "Optical WDM Networks", Springer, 2006.
6. Gerd Keiser, Wiley-IEEE "FTTx Concepts and Applications"
7. James Farmer, Brian Lane, Kevin Bourg, Weyl Wang, "FTTx Networks" 1st Edition November 2016.

PGC-601 – Research Methodology and IPR

Course Outcomes:

CO-1	Understanding the fundamentals of research and its methodology
CO-2	Choose the appropriate research design and develop appropriate 3 hypotheses for a research project
CO-3	Knowledge of manuscript preparation, patents and Intellectual property
CO-4	Technology transfer and application of IPR in various domains

Syllabus:

Units Divisions	Syllabus Details	Hours
Unit I:	Meaning of research problem, Sources of the research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of the research problem. Approaches of investigation of solutions for	**9**

	research problem, data collection, analysis, interpretation, Necessary instrumentations	
Unit II:	Effective literature studies approach, analysis Plagiarism, Research ethics	**6**
Unit III	Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee	**6**
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.	**9**
Unit V	Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications	**9**
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.	9

References Textbooks:

21. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for
22. science & engineering students’”
23. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
24. Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for beginners”
25. Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd,2007.
26. Mayall, “Industrial Design”, McGraw Hill, 1992.
27. Niebel, “Product Design”, McGraw Hill, 1974.
28. Asimov, “Introduction to Design”, Prentice Hall, 1962.
29. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New Technological Age”, 2016.
30. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008

PGC-602 – Audit I and II

Course Outcomes:

CO-1	
CO-2	
CO-3	
CO-4	
CO-5	

Syllabus:

Units Divisions	**Syllabus Details**
Unit I:	English for Research Paper Writing
Unit II:	Disaster Management
Unit III	Sanskrit for Technical Knowledge

Unit IV	Value Education
Unit V	Constitution of India
Unit VI	Pedagogy Studies
Unit VII	Stress Management by Yoga
Unit VIII	Personality Development through Life Enlightenment Skills

AP 701 Laser & Optical Communication Laboratory 1

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 polarisation states using polarisation 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 Microbending 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
13. Fiber to Fiber splicing and splicing loss measurement.
14. Setting up of Mach-Zender interferometer
15. Measurement of Photoluminiscence 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 (**compulsory for all**)

Note: Every student should perform a minimum of 15 experiments from the above list.

AP 702 Lasers & Optical Communication 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 (**compulsory for all**)

Note: Every student should perform a minimum of 15 experiments from the above list.

________________________END OF THE COURSE CONTENT____________________

M. Tech. in Optoelectronics and Communication Systems (Optical Communication and Photonics)

The rapid growth of networks and the internet over the past decade has been enabled by advances in photonics technology. Optical communication networks provide the high capacity ubiquitous connectivity that forms the backbone of global internet. Today, optics has become the way by which most of the information is communicated around the globe and is the only technology that is capable of meeting the exponentially growing demand for communicating information. The programme intends to impart training to selected candidates in the field of Optical Communication and Photonicsthat would enable them to meet the challenges in this rapidly developing field.

Stakeholders:

(iii) Sponsored candidates from 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:

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.

Semester I

Sl No	Course Code	Course Name	Contact Hours/week		Credits
			L	P/T (in Hr)	
1	AP 621	Fundamentals of Laser 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	Laser & Optical Communication 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 651	Broadband Communication Systems	3	1	4
2	AP 652	Advanced Optical Communication	3	1	4
3	AP 653	Optical Networks	3	**1**	4
4	AP 702	Laser & Optical Communication Laboratory – II	0	8	4
5	AP 6XX	Elective – I	3	1	4
6	AP 6XX	Elective – II	3	1	4
7	PGC-602	Audit 1 and 2	2	0	0
		TOTAL	**17**	**9**	**24**

Semester III:

Sl. No.	Course Code	Course Name	**Contact Hours /week**		**Credits**
			L	T / P	
1.	AP 681	M.Tech Dissertation Phase – I	28**		14
		Total	28		14

Semester IV:

Sl. No.	Course Code	Course Name	**Contact Hours /week**		**Credits**
			L	T / P	
1.	AP 682	M. Tech. Dissertation Phase – II	28**		14
		Total	28		14

<u>List of Electives</u>

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
7	AP 631	Laser Applications
8	AP 632	Computational Photonics

AP-621 –

Fundamentals of Laser and Laser Systems

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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**

References Textbooks:

6. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.
7. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
8. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988
9. B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007)
10. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).

AP-622 – Optical Electronics

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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	**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.	**10**
Unit V	**Magneto-optics**: Principles, Faraday effect, Gyrotropic permittivity, Kerr rotation and Kerr ellipticity, Applications.	**6**

References Textbooks:

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.

12. O. Svelto, Principles of Lasers, Plenum Press, New York, 1998.
13. P. W. Milonni and J. H. Eberly, Lasers, Willey Inter Science, 1988.
14. A. K. Ghatak and K. Thyagarajan, Lasers: Theory & Applications, Macmillan India Limited, 2003.

AP-623 – Introduction to Fiber Optics

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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**

References Textbooks:

6. A.K. Ghatak & K. Thyagarajan, Introduction to Fiber Optics, Cambridge University Press 1998
7. G. Kaiser, Optical Fiber Communication, 4th Edition, Tata McGraw Hill 2008
8. J.C. Palais, Fiber Optic Communications, 4th Ed., Prentice-Hall Inc 1998
9. J.P. Dakin & B Culshaw, Optical Fiber Sensors, Vol. 1&2., Artech House 1998
10. K.T.V. Grattan & B.T. Meggitt, Optical Fiber Sensor Technology, Vol. 2, 1988

AP-624 – Semiconductor Photonic devices

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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**

References Textbooks:

9. P. Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India (1995).
10. G. Ghione, Semiconductor Devices for High-Speed Optoelectronics, Cambridge University Press (2009)
11. A. Yariv and P. Yeh, Photonics: Optical Electronics in Modern Communication, Oxford University Press (2007), 6th Ed., Ch.15-17.
12. G. Keiser, Optical Fiber Communications, McGraw-Hill Inc., 3rd Ed. (2000), Ch.4, 6.
13. J. Singh, Semiconductor Optoelectronics: Physics and Technology, McGraw-Hill Inc. (1995).
14. J. M. Senior, Optical Fiber Communication: Principles and Practice, Prentice Hall of India, 2nd Ed. (1994), Ch.6-8.
15. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, John Wiley & Sons, Inc., 2nd Ed. (2007), Ch.16, 17, and 18.
16. S. M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 3rd Ed. (2021).

AP-625 – Quantum mechanics for Engineers

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

Syllabus:

Units Divisions	**Syllabus Details**	**Hours**
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 atoms: 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**

References Textbooks:

5. Quantum Physics of Atoms, molecules, solids nuclei and particles by Robert Eisberg and Robert Resnick Wiley publishing
6. Introduction to Quantum Mechanics by David Griffiths Pearson Publishing
7. Quantum Mechanics by B H Bransden and C J Joachain Pearson Publishing
8. Zettili, Nouredine. "Quantum mechanics: concepts and applications." John Wiley and Sons, Ltd., Publishing 2nd Ed. (2009).

AP-651 – Broadband Communication Systems

Course Outcomes:

CO-1	Familiarize to the concepts of Communication technology
CO-2	Interpret the working principle of different types of conventional and Broadband technologies, in terms of signal modulation used
CO-3	Understand working of Cellular Communication systems
CO-4	Analyse the working of GSM Technology and complex modulation techniques used
CO-5	Summarize different applications from 4G to 6G Communication systems

Syllabus:

Units	**Syllabus Details**	**Hours**
Unit I:	Introduction to Basic Conventional Communication Systems – Modulation, Digital & Analog Communication systems. Introduction to Broadband Network Architectures, Concept of layered Models,OSI Layers and TCP/IP Models	**9**
Unit II	Basic Broadband Technologies: Internet Protocol Suite, IPv6, Basics of Intranet & Extranet technologies, X.25 Technology, Frame Relay,	**9**

	Frame Relay Standards, Types of VPN and General Architecture, Fiber Channel Technology & topologies.	
Unit III	Cellular Communication: Analog Cellular Communications, The Cell site, The Mobile Telephone Switching Office (MTSO), Cell site Configurations, Tiered sites, Reuse of Frequencies, Allocation of Frequencies	**6**
Unit IV	Global Services Mobile Communications (GSM), Wireless Data Communication (Mobile IP) and GPRS: Analog to Digital Movement, GSM Architecture, Mobile Equipment (MS), BTS, BSC, BSS, MSC, VLR, IP Routing, Applications That Demand Mobile IP, Variations in Data Communications (Wireless), Possible Drawbacks with Wireless, Wireless Data Technology Options, The GSM Phase II Overlay Network, Circuit−Switched or Packet−Switched Traffic, GPRS Radio Technologies, PDP Contexts,	**9**
Unit V	Wireless Technology and Evolution of Modulation Technique – QAM, FDM, Orthogonal FDM, Adaptive Modulation Techniques. 4G & 5G:Introduction to 4G Standards, Introduction to 4G Architecture, components & basic internet & communication call flows. Introduction to 5G standards, basic 5G architectures, 5G services, Recent trends and applications in 5G, Massive Multiple-Input Multiple-Output (MIMO) Wireless Systems	**12**

References Textbooks:

8. Cajetan M. Akujuobi, Matthew N.O. Sadiku, Introduction to Broadband Communication Systems,Chapman and Hall/CRC, 2007.
9. Robert C. Newman, Broadband Communications Prentice Hall, NJ, USA, 2001.
10. Rajiv Ramaswami, Kumar N. Sivarajan and G. H. Sasaki, “Optical Networks: A Practical Perspective”, Elsevier, Third Edition, 2010.
11. B Sklar, “Digital Communications: Fundamentals and Applications” PH, 2001
12. Kuhn Paul J., Ulrich,Roya, “Broadband Communications” 1998.
13. SofoklisKyriazakos, River Publishers, 4G Mobile and Wireless Communications Technologies.
14. Jonathan Rodriguez, Wiley Publications, Fundamentals of 5G Mobile Networks

AP-652 – Advanced Optical Communication

Course Outcomes:

CO-1	Familiarize to the basics of Optical Communications
CO-2	Analyze the working principle of different types of Optical Components, Modules, and Subsystems
CO-3	Scrutinize the Advanced Modulation and Multiplexing Techniques
CO-4	Illustrate the practical implementation of Loss and Dispersion Management in Optical Fiber Communication
CO-5	Summarize different types of Nonlinear Effects in Fibers

Syllabus:

Units	Syllabus Details	Hours

Unit I:	**Basics of Optical Communications:** Model of Optical Communication, Signal Propagation Effects in Optical Fibers, Fiber Attenuation and Insertion Losses, Chromatic Dispersion Effects, Polarization-Mode Dispersion (PMD), Fiber Nonlinearities, Generalized Nonlinear Schrödinger Equation, Noise Sources in Optical Channels, Introduction to Quantum Communication	**9**
Unit II	**Optical Components, Modules, and Subsystems:** Key Optical Components, Optical Transmitters, Optical Receivers, Optical Signal-To-Noise Ratio, Receiver Sensitivity and Q Factor, Optical Amplifiers, Optical Couplers, Optical Filters, Optical Isolator, Optical Circulator, WDM Multiplexers and Demultiplexers, OFDM, Principles of Coherent Optical Detection, Coherent Optical Balanced Detectors	**9**
Unit III	**Advanced Modulation and Multiplexing Techniques:** Channel Capacity Theorem, Signal Space Theory, Pulse amplitude modulation (binary and M-ary, QAM), Pulse position modulation (binary and M-ary), Carrier modulation (M-ary ASK, PSK, FSK, DPSK), Continuous phase modulation (QPSK and variants, MSK, GMSK), Trellis Code Modulation, Probability of Error & Bit Error Rate, MIMO Fundamentals, Optical Time-Division Multiplexing, Subcarrier Multiplexing, Code-Division Multiplexing, Polarization-Division Multiplexing (PDM) and 4-D Signalling	**9**
Unit IV	**Loss and Dispersion Management:** Compensation of Fiber Losses, Role of Dispersive Effects, Periodically Amplified Lightwave Systems, Dispersion Problem in SMF, Dispersion-Compensating Fibers, Fiber Bragg Gratings, Dispersion-Equalizing Filters, Optical Phase Conjugation, Channels at High Bit Rates,	**9**
Unit V	**Nonlinear Effects in Fibers:** Origin of Linear and Nonlinear Refractive Indices, Second and Third Order nonlinearities, Self-phase modulation, Cross Phase modulation, Four-wave mixing, Combined Effect of Dispersion and SPM, Stimulated Raman scattering, Stimulated Brillouin scattering, Solitons communication systems.	**9**

References Textbooks:

1. G. P. Agarwal, Fiber-Optic Communication Systems, 4th Ed., Wiley, 2010.
2. Advanced Electronic Communications Systems, by Wayne Tomasi, 6 Edition Pearson Education.
3. Kumar, Shiva, and M. Jamal Deen. Fiber optic communications: fundamentals and applications. John Wiley & Sons, 2014.
4. Djordjevic, Ivan B. Advanced optical and wireless communications systems. Heidelberg: Springer, 2018.

AP-653 – Optical Networks

Course Outcomes:

CO-1	Familiarize to the basics of Optical Networks
CO-2	Analyze the working principle of different WDM Network elements, its control and management
CO-3	Scrutinize the Advanced Modulation and Multiplexing Techniques

CO-4	Illustrate the practical implementation of Loss and Dispersion Management in Optical Fiber Communication
CO-5	Describe different FTTx Installation, Testing and Management

Syllabus:

Units	Syllabus Details	Hours
Unit I:	**Introduction to the Basics of Optical Networks:** Telecommunications Network Architecture, Services, Circuit Switching and Packet Switching, The Optical Layer, Transparency and All-Optical Networks, Optical Packet Switching, Transmission Basics, Network Evolution, SONET/SDH, Optical Transport Network, Generic Framing Procedure, Ethernet, IP, Multiprotocol Label Switching, Resilient Packet Ring, Storage-Area Networks	**9**
Unit II	**WDM Network elements, Control and Management:** Optical Line Terminals, Optical Line Amplifiers, Optical Add/Drop Multiplexers, Optical Crossconnects, Network Management Functions, Optical Layer Services and Interfacing, Layers within the Optical Layer, Multivendor Interoperability, Performance and Fault Management, Configuration Management, Optical Safety	**9**
Unit III	**Network Survivability and WDM Network Design:** Basic Concepts, Protection in SONET/SDH, Protection in the Client Layer, Why Optical Layer Protection, Optical Layer Protection Schemes, Interworking between Layers, Network Reliability and Security, Cost Trade-Offs: A Detailed Ring Network Example, LTD and RWA Problems, Dimensioning Wavelength-Routing Networks, Wavelength Conversion in WDM Network, Statistical Dimensioning Models, Traffic Grooming in Optical Networks.	**9**
Unit IV	**Photonic Packet Switching and FTTx:** Optical Time Division Multiplexing, Synchronization, Header Processing, Buffering, Burst Switching, Testbeds, Introduction to FTTx, Fiber to the Home Architectures, FTTH in MDUs (Multiple Dwelling Units), FTTH PON Types, FTTH PON (Passive Optical Network), Triple Play Systems (BPON, GPON, EPON, RFOG) WDM and PON Other Uses for PONs, FTTX hardware and components (Cables, Splitters, Cabinets, Subscriber components).	**9**
Unit V	**FTTx Installation, Testing and Management:** Outdoor cable installation, Duct, aerial, direct burial, Micro-duct solutions, Drop cable installation, Fiber terminations on with pigtail, Splicing and joint closing, Testing FTTH (Key factors affecting network, Testing during construction, Testing for commissioning).	**9**

References Textbooks:

1. Rajiv Ramaswami, Kumar N. Sivarajan and G. H. Sasaki, “Optical Networks: A Practical Perspective”, Elsevier, Third Edition, 2010.
2. P.E. Green, Jr., “Fiber Optic Networks”, Prentice Hall, NJ, 1993.

3. C. Siva Ram Moorthy and Mohan Gurusamy, “WDM Optical Networks: Concept,Design and Algorithms”, Prentice Hall of India, IstEdition, 2002.
4. Djordjevic, Ivan B. Advanced optical and wireless communications systems. Heidelberg: Springer, 2018.
5. Biswanath Mukherjee, “Optical WDM Networks”, Springer, 2006.
6. Gerd Keiser, Wiley-IEEE “FTTx Concepts and Applications”
7. James Farmer, Brian Lane, Kevin Bourg, Weyl Wang, “FTTx Networks” 1st Edition November 2016.

AP-641 – High Power Lasers

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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**

References Textbooks:

8. High Power Lasers–Directed Energy Weapons Impact on Defence and Security, A. Mallik, DRDO MONOGRAPHS/SPECIAL PUBLICATIONS SERIES, 2012
9. H. Injeyan and G. Goodno, High Power Laser Handbook, McGraw-Hill Professional; 1 edition (April 25, 2011)
10. AK Jha, Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, Wiley, 2000
11. Ter-Mikirtychev and Vartan, Fundamentals of fiber lasers and fiber amplifiers, Springer Series in Optical Sciences, Vol. 181, 2014.
12. B. Zohuri, Directed Energy Weapons Technologies, CRC Press, 1 ed., 2012.
13. V VApollonov, High-Power Optics: Lasers and Applications, Springer International Publishing, Switzerland, 2015
14. Alastair D. McAulay, MILITARY LASER TECHNOLOGY FOR DEFENSE: Technology for Revolutionizing 21st Century Warfare, John Wiley & Sons, Singapore, 2011

AP-642 – Terahertz Devices and Applications

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 technologyfor imaging, sensing and communications

Syllabus:

Units	Syllabus Details	Hours
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,	**9**

	Polarizer, Mirrors, Isolator, Circulator, Cameras, Fabrication Technologies, Metamaterial THz devices, Spintronic THz components.	
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, Space Communication, Cutting-edge terahertz technologies	**9**

References Textbooks:

6. A. Rostami, H. Rasooli, H. Baghban, Terahertz Technology: Fundamentals and Applications, Germany, Springer, 2011.
7. R. E. Miles, P. Harrison, D. Lippens, Terahertz Sources and Systems ", Dordrecht: Kluwer, Springer, 2000.
8. K. Sakai, Terahertz Optoelectronics, Springer, 2004.
9. H.-J. Song, T. Nagatsuma, Handbook of Terahertz Technologies, Devices and applications, Pan Stanford Publishing Pte. Ltd., 2015.
10. D. Saeedkia, Handbook of Terahertz Technology for Imaging, Sensing and Communications, Woodhead Publishing, 2013.

AP-643 – Free Space Optical Communications

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

Syllabus:

Units Divisions	**Syllabus Details**	**Hours**
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**

References Textbooks:

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
4. Morris Katzman, Laser Satellite Communications. Prentice Hall Inc 1991
5. Infrared Technology: Applications to Electro-Optics, Photonic Devices and Sensors, A.K. Jha

AP-644 – Nanophotonics

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

Syllabus:

Units Divisions	**Syllabus Details**	**Hours**
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 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, Designing photonics crystal for application: A Mirror, A Waveguide and A Cavity.	**12**

References Textbooks:

7. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, Christophe Caloz,Tatsuo Itoh, John Wiley and Sons,2006

8. Optical Metamaterials, Fundamentals and Applications, Wenshan Cai Vladimir Shalaev, Springer, 2010.

9. John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, and Robert D. Meade,Photonic Crystal: Molding Light Flow of Light, Princeton University Press, 2008.

10. Graham T. Reed and Andrew P. Knights, Silicon Photonics: An Introduction, JohnWiley and Sons Ltd, 2004

11. Metamaterials: Physics and Engineering Explorations, Nader Engheta Richard W. Ziolkowski, Wiley and Sons,2006

12. Negative-Refraction Metamaterials Fundamental Principles and Applications, G. I. Eleftheriades K. G. Balmain,Wiley and Sons,2005

AP-645 – Nonlinear and Quantum Optics

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

Syllabus:

Units Divisions	**Syllabus Details**	**Hours**
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,	**9**

	Self-focusing, Optical Solitons; Optical phase conjugation and Optical bistability. Stimulated Raman Scattering and Stimulated Brilluoin Scattering.	
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**

References Textbooks:

12. A. Yariv and P. Yeh, Optical waves in crystals: propagation and control of laser radiation, Wiley, New York, 2002.
13. Peter E. Powers, Fundamentals of Nonlinear Optics, CRC Press, 2011.
14. A. Yariv, Quantum Electronics, John Wiley, 1989.
15. Y. R. Shen, The Principles of Non-linear Optics, John Wiley & Sons, 2003
16. R. W. Boyd, Nonlinear Optics, Academic Press, 2008.
17. H.M. Moya-Cessa and F. Soto-Eguibar, Introduction to Quantum Optics (Rinton Press 2011).
18. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, 2nd ed..John Wiley, 2007.
19. A. M. Weiner, Ultrafast Optics, Wiley Books, 2008
20. Gerry, Christopher; Knight, Peter, Introduction to Quantum Optics. Cambridge University Press, 2004.
21. L. Mandel, E. Wolf, Optical Coherence and Quantum Optics (Cambridge 1995).
22. D. F. Walls and G. J. Milburn, Quantum Optics (Springer 1994).

AP-646 – Integrated Optics and Silicon Photonics

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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	12

	waveguides. Rectangular and channel waveguides; modal solutions using the effective index and perturbation methods.	
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 andacousto-optic waveguide devices. Directional couplers, optical switch; phase andamplitude 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, MachZehnder 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**

References Textbooks:

8. William S. C. Chang, Fundamentals of Guided-wave optoelectronics devices, Cambrige University Press,2009
9. G. T. Reed and A. P. Knights, Silicon Photonics An Introduction, John Wiley & Sons, 2004
10. T. Tamir, Ed. Integrated Optics, Springer, 2nd Ed., 1983.
11. R. Hunsperger, Integrated Optics: Theory and Technology" 6th Ed., Springer - 2009.
12. H. Nishihara, M. Haruna, and T. Suhara "Optical Integrated Circuits", McGraw-Hill, 1988.
13. K Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2005.
14. *Ghatak* .A.K., and K. *Thyagarajan* ,Optical Electronics, Cambridge, 1989.

AP-631 – Laser 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

Syllabus:

Units	Syllabus Details	Hours
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**

References Textbooks:

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
4. K. Bharat, Laser Safety Tools and Training, CRC Press 2009
5. K. Nagothu, New Paradigms for Underwater Communication, ProQuest 2009

AP-632 – Computational Photonics

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

Syllabus:

Units Divisions	Syllabus Details	Hours
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 Modeling:** Simulation and modeling of single mode and multimode optical fiber using mode solver, FBG and Chirped FBG synthesis, photonic crystal fiber simulation	**9**
Unit V	**Nanodesign:** Mask designing for nanofabrication of different device geometry	**6**

References Textbooks:

4. S. Sujecki, Photonics Modelling and Design, CRC Press, 2015.
5. K. Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2000.
6. A. Taflove, Computational Electrodynamics: The Finite-Difference Time Domain Method. Norwood, MA: Artech House, 1995.

PGC-601 – Research Methodology and IPR

Course Outcomes:

CO-1	Understanding the fundamentals of research and its methodology
CO-2	Choose the appropriate research design and develop appropriate 3 hypotheses for a research project
CO-3	Knowledge of manuscript preparation, patents and Intellectual property
CO-4	Technology transfer and application of IPR in various domains

Syllabus:

Units Divisions	Syllabus Details	Hours
Unit I:	Meaning of research problem, Sources of the research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of the research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations	**9**

Unit II:	Effective literature studies approach, analysis Plagiarism, Research ethics	**6**
Unit III	Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee	**6**
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.	**9**
Unit V	Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications	**9**
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.	9

References Textbooks:

31. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for
32. science & engineering students’”
33. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
34. Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for beginners”
35. Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd,2007.
36. Mayall, “Industrial Design”, McGraw Hill, 1992.
37. Niebel, “Product Design”, McGraw Hill, 1974.
38. Asimov, “Introduction to Design”, Prentice Hall, 1962.
39. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “Intellectual Property in New Technological Age”, 2016.
40. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008

PGC-602 – Audit I and II

Course Outcomes:

CO-1	
CO-2	
CO-3	
CO-4	
CO-5	

Syllabus:

Units Divisions	**Syllabus Details**
Unit I:	English for Research Paper Writing
Unit II:	Disaster Management
Unit III	Sanskrit for Technical Knowledge

Unit IV	Value Education
Unit V	Constitution of India
Unit VI	Pedagogy Studies
Unit VII	Stress Management by Yoga
Unit VIII	Personality Development through Life Enlightenment Skills

AP 701 Laser & Optical Communication Laboratory 1

Pre-requisite: Laser safety tutorials/video demonstration of Laser safety followed by written test

21. Michelson Interferometer: Setting up Michelson interferometer using a highly monochromatic laser source, evaluation of laser wavelength by fringe counting.
22. Beam Width, Divergence and M^2 measurement of He-Ne/Diode Laser with and without collimation lens.
23. Determination of the Electrical and Optical Characteristics of LED and Laser diode.
24. Designing of Optical Window, Concave and Convex Lens
25. Detection of polarisation states using polarisation components like polarizers, waveplates etc.
26. Analysis of various light source spectra using OSA.
27. Determination of the refractive index profile of a multimode and single mode fiber by the transmitted near field scanning technique and measurement of NA.
28. Macro and Microbending loss in optical fibers and its application
29. Measurement of Photodiode characteristics
30. Study of Fraunhofer diffraction pattern of a rectangular and circular aperture.
31. Fiber optic link design
32. Measurement of attenuation and dispersion in optical fibers
33. Fiber to Fiber splicing and splicing loss measurement.
34. Setting up of Mach-Zender interferometer
35. Measurement of Photoluminiscence of an active materials using PL measurement setup.
36. Design of driver circuit for LED and Laser diode
37. Characterization of Erbium Doped Fiber Amplifier
38. Pulse width measurement of different laser using auto-correlator.
39. Holography
40. One Mini project (**compulsory for all**)

Note: Every student should perform a minimum of 15 experiments from the above list.

AP 702 Lasers & Optical Communication Laboratory-II

20. Characterization of Fiber Bragg grating
21. Phase Sensitive detection technique using lock-in amplifier.
22. Power budget analysis using Optical Time Domain Reflectometer (OTDR)
23. Study of Time Division Multiplexing of digital signals
24. Study of a Wavelength Division Multiplexing (WDM) in optical fiber link
25. Study of Add/drop multiplexer
26. Study of Bit error rate and Eye pattern analysis
27. Setting up a Free space Laser Communication experiment link

28. Study of Electro-optic effect (Pockel and Kerr)
29. Measurement of third order nonlinear optical coefficient using Z-scan
30. Study of Faraday effect
31. Design of a fiber optic sensor
32. Line coding and decoding, voice coding
33. Measurement of insertion loss of an isolator, coupler and multiplexer
34. Beat length measurement in birefringent fibers.
35. Laser Raman Spectroscopy Experiments
36. M^2 measurement of different lasers
37. Measure the effect of the relative motion by using SAGNAC Interferometer
38. Mini project (**compulsory for all**)

Note: Every student should perform a minimum of 15 experiments from the above list.

END OF THE COURSE CONTENT

SCHOOL OF QUANTUM TECHNOLOGY
M. Tech. in Quantum Computing
(Spl: Quantum Communication & 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 a Master/Integrated degree or equivalent in Physics, Applied Physics, Electronic Science, Photonics
(OR)
B.E. / B.Tech / BSc. (Eng.) or equivalent in any branch

Stakeholders:

i. Sponsored candidates from Army, Navy, Air Force, DRDO Laboratories, Public Sector Undertakings, and other departments

ii. Graduates in the relevant field of science/technology from recognized Universities across the country.

Organization: The M. Tech. Program is of four-semester duration. In each of the first two semesters, there are five classroom teaching classes and one experimental laboratory. There will be continuous evaluation examinations, three internal examinations, and a final semester examination for every course. A half-yearly evaluation of the project takes place at the end of the third semester. At the end of the last semester, the student submits a thesis and makes a presentation about the project, which is evaluated by the Internal and External examiners.

SEMESTER I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	**QT601**	Introduction to optics and photonics	4	0	4
2	**QT602**	Introduction to Quantum Mechanics	4	0	4
3	**QT603**	Introduction to Quantum Computing	4	0	4
4	**QT604**	Quantum information theory	4	0	4
5	**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
6	**QT610**	Quantum Technology Laboratory-1	0	8	4
7	**PGC-601**	Research Methodology and IPR	2	0	2
		Total	**21**	**10**	**26**

SEMESTER II

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	**QT 606**	Advanced Quantum communications	4	0	4
2	**QT 607**	Quantum Metrology and Sensing	4	0	4
3	**QT 608**	Quantum Computing II	4	0	4
4	**QT 611**	Quantum Technology Laboratory-2	0	8	4
5		Elective I	4	0	4
6		Elective – II	4	0	4
7	**PGC-602**	Audit Course	2	0	0
		Total	**22**	**8**	**24**

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	**QT 623**	Machine Learning

SEMESTER III

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

** Contact hours/week

SEMESTER IV

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

** Contact hours/week

PROGRAM OUTCOMES

PO1	To accustomed and gain sufficient knowledge in all verticals of Quantum technology (Quantum computing, Quantum communications, and Quantum sensing)

PO2	An ability to independently carry out research and development work to handle actual problems utilizing quantum resources
PO3	Mastery over the area of specialization at a level higher than their previous degree to meet the requirements of emerging Quantum-based laboratories and companies
PO4	Next-generation workforce in Quantum technology

PROGRAM SPECIFIC OUTCOMES

PSO1	Practical implementation of the knowledge of basic and advanced optics, electronics, quantum technologies, and quantum algorithm tools to integrate into the systems to enhance their performance and solve complex problems in nature.
PSO2	Fluent in design and model systems for Quantum communications and Quantum sensing using appropriate technology and software tools.
PSO3	Able to handle and develop quantum technologies towards quantum-enabled society

QT 601: INTRODUCTION TO OPTICS AND PHOTONICS

SYLLABUS:

Unit	Syllabus Details
Unit I	**Ray optics and Maxwell's equations:** Maxwell's equations and solution to Maxwell's equation. Paraxial waves, ray optics and ABCD matrices. 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 Fibers. Fiber Attenuation, Absorption losses, Scattering losses, Radiation losses, Bending losses, Dispersion

	in fibers, Effect of dispersion in communication link

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 OUTCOMES:

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

QT 602: QUANTUM MECHANICS

SYLLABUS:

Unit	Syllabus Details
Unit I	**Basic introduction to Quantum Mechanics:** Wave-particle duality and matter waves. The double slit experiment. The Stern-Gerlach experiment. The Schrödinger equation, square integrable functions and wavefunctions. Particle in an infinite potential well and bound states. Quantum Tunneling. Position and momentum eigenstates.
Unit II	**Linear algebra and complex vectors spaces:** Hilbert space. State vectors. Basis sets and the Gram-Schmidt orthogonalization. Unitary operators, operator adjoints and self-adjoint operators (Hermitian operators). Eigenvalues and eigenstates. Eigen basis and spectral decomposition of operators. The Hamiltonian operator. Position, momentum and energy eigenstates. The density operator. Complete set of commuting operators and Observables in quantum mechanics.
Unit III	**Quantum Measurements:** Projective measurements rank one projectors. Positive Operator Valued Measures. Expectation values and Variance. The Heisenberg uncertainty relations. Pauli's exclusion principle, Fermi and Bose particles.
Unit IV	**Harmonic Oscillator, Angular momentum and other problems:** The Linear Quantum Harmonic Oscillator. Creation, annihilation operators and number operators their properties. Spin- half quantum systems and Pauli operators. The Angular Momentum problem. Time evolution of quantum systems: The Heisenberg, Schrödinger and Interaction pictures. Time evolution of density operators and the Born formula. Approximation methods.

References

1. Quantum Mechanics, Claude Cohen-Tannoudj, B. Diu and F. Laloë, Volume-I, WILEY-VCH, New York
2. Joachim Stoke, Dieter Suter, Quantum Computing: A *Short* Course from Theory to Experiment, WILEY-VCH GmbH & Co, 2004.
3. L.I Schiff, Quantum Mechanics, McGraw-Hill, 1968.

4. The Principles of Quantum Mechanics, Clarendon Press, Oxford, 1958.
5. David J. Griffiths, Introduction to Quantum Mechanics, Cambridge University Press, 2017
6. Kurt Gottfried, Quantum Mechanics: Fundamentals, Springer (2Ed.), 2003

COURSE OUTCOMES:

CO-1	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.

QT 603: INTRODUCTION TO QUANTUM COMPUTING

SYLLABUS:

Unit	Syllabus Details
Unit I	**Introduction:** Introduction to Quantum computing, prehistory of quantum computing, Requirements for quantum computers (DiVincenzo criteria), Quantum Bits, Qubit measurements, qubit evolution, mixed states and density operators, Tensor product and compound quantum systems, two qubits and multiple qubits systems. Quantum operation on a multiqubit systems, Quantum entanglement, No-cloning theorem, Super-dense coding, Quantum Teleportation.
Unit II	**Quantum Gates:** Classical Logic gates, Irreversible gates, Universal gates, reversible gates, universal reversible gates, Quantum logic gates, single qubit gates, Rotation gates, multiqubit gates, controlled quantum gates, Universal quantum gates, quantum circuit identities.
Unit III	**Quantum Algorithms:** Quantum Parallelism, Phase kick-back, Deutsch's problem, Deutsch-Jozsa algorithm, Quantum Fourier transform, Quantum Phase estimation, Grover's search algorithm, Simon's problem, Shor's algorithm.

References

1. Joachim Stoke, Dieter Suter, Quantum Computing: A Short Course from Theory to Experiment, WILEY-VCH GmbH & Co, 2004
2. Chris Bernhardt, Quantum Computing for Everyone, The MIT Press, 2019
3. Nielsen, Michael A.; Chuang, Isaac L., Quantum Computation and Quantum Information Cambridge: Cambridge University Press, 2012
4. Philip Kaye, Raymond La Flamme and Michele Mosca. An Introduction to quantum Computing, Oxford. University Press.

COURSE OUTCOMES:

CO-1	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.

QT 604: QUANTUM INFORMATION THEORY

SYLLABUS:

Unit	Syllabus Details
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.

<u>References</u>

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 OUTCOMES:

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.

QT 605: HIGH PERFORMANCE DSP USING FPGA

SYLLABUS:

Unit	Syllabus Details
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.

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 (in QT 605):

Sl. No.	Name of experiments
01.	The Basic Design Flow of DSP Implementation in FPGA. To understand use of Xilinx System Generator. To understand Xilinx Synthesis Technology or XST. Familiarization of Simulink, Signal Processing Toolbox, Signal Processing Block-set.
02.	Implementation of Dual Port RAMS, Addressable Shift Register, FIFO And ROM in FPGA. Familiarization with Memory Blocks implementation in FPGA. To Understand FGPGA Hardware. Familiarization of XUP board (Vertex-5).
03.	Implementation of M Code Adder in FPGA This exercise provides an introduction to the integration of M Code into a System Generator System. To understand the functionality of a basic 2-input adder is interpreted from the M-code.
04.	Generation of Simulink System Period To understand Simulink system periods, and confirm the meaning of this parameter from the simulation results.

COURSE OUTCOMES:

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

QT 610: QUANTUM TECHNOLOGY LABORATORY-I

SYLLABUS:

Sl. No.	Name of experiments
01.	Study of Optical lens and lens systems
02.	Fibre splicing and OTDR measurement
03.	Study of Polarizer, Polarizing and Non-polarizing BS, QW, HW, FW Plates
04.	Polarization properties of laser with and without QW, HW and FW Plates
05.	Fourier Optics
06.	Characterization Diode laser system
07.	Laser beam-divergence and M^2 measurement
08.	Setting up Michelson interferometer
09.	Setting up Mach-Zehnder interferometer
10.	Determination of the refractive index profile of a multimode and single mode fibre by the transmitted near field scanning technique and measurement of NA.
11.	Measurement of attenuation and dispersion in optical fibres
12.	WDM Mux, Demux and add drop multiplexing

13.	Fibre amplifier
14.	Particle nature of photons
15.	Demonstration of BB84 protocol
16.	Quantum random number generation

COURSE OUTCOMES:

CO-1	Understanding and Hands on experience on optical elements and Fibers.
CO-2	Construction of various optical interferometers
CO-3	Introduction to Quantum phenomena.

PGC-601: RESEARCH METHODOLOGY AND IPR

SYLLABUS:

Unit	Syllabus Details
Unit I	Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations
Unit II	Effective literature studies approaches, analysis Plagiarism, Research ethics,
Unit III	Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee
Unit IV	Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.
Unit V	Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications
Unit VI	New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

<u>References Textbooks</u>

41. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for
42. science & engineering students’”
43. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
44. Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for beginners”
45. Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd,2007.
46. Mayall, “Industrial Design”, McGraw Hill, 1992.
47. Niebel, “Product Design”, McGraw Hill, 1974.
48. Asimov, “Introduction to Design”, Prentice Hall, 1962.
49. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “ Intellectual Property in New Technological Age”, 2016.
50. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008

<u>COURSE OUTCOMES:</u>

CO-1	Understanding the fundamentals of research and its methodology
CO-2	Choose the appropriate research design and develop appropriate research hypothesis for a research project
CO-3	Knowledge of manuscript preparation, patents and Intellectual property
CO-4	Technology transfer and application of IPR in various domains

QT 606: ADVANCED QUANTUM COMMUNICATIONS

SYLLABUS:

Unit	Syllabus Details
Unit I	Elements of classical cryptography (basic understanding), RSA public and private key distribution, Block ciphers, American encryption standards (AES), Authentication and Wegman-Carter protocol, Universal hashing techniques
Unit II	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

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 OUTCOMES:

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

QT 607: QUANTUM METROLOGY AND SENSING

SYLLABUS:

Unit	Syllabus Details
Unit I	Time dependent perturbation theory, applications like fine structure constant, hyper-fine splitting, Zeeman effect, Introduction to atom-light interactions, Rabi model, Optical cavities, Introduction to laser and their applications to metrology
Unit II	Fisher information, Cramer-Rao bound (classical and quantum), Standard quantum limit (shot-noise limit) and Heisenberg limit (squeezed light), Ghost imaging (quantum enhanced imaging), Quantum illumination, Quantum reading, Quantum RADAR, Super-resolution with OAM beams and vector beams
Unit III	Cold atoms, Gravimeters and time-stamping based on atom 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

Textbook/ References

1. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, 2nd ed..John Wiley, 2007
2. A. Yariv, Quantum Electronics, John Wiley.
3. Research papers/Articles as required

COURSE OUTCOMES:

CO-1	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

QT 608: QUANTUM COMPUTING II

SYLLABUS:

Prerequisite: Quantum computing I

Unit	Syllabus Details
Unit I	Quantum noise and error correction codes: Noise and the Di-vincenzo criteria. The classical error correction model. The classical three bit code. Quantum error correction. Three and nine bitcodes and the stabilizer codes.
Unit II	**Quantum computing with Qiskit:** Qubits; multi-qubits systems. Quantum operation on a multi-qubit systems, Reversible Gates; Quantum Gates;
Unit III	**Implementation of Quantum Algorithms with Qiskit:** Quantum Parallelism, Phase kick-back, Deutsch's problem, Deutsch-Jozsa algorithm, Quantum Fourier transform, Quantum Phase estimation, Grover's search algorithm, Simon's problem, Shor's algorithm.
Unit IV	**Physical realization of qubits:** introduction to Super conducting qubits and ion traps models, Linear optical quantum computing, Single qubit gates, Computational complexities: brief introduction, models , How to compute quantum volume using free-accessible quantum sources from IBM.

Reference Books

1. Michael A. Nielsen and Isaac L. Chuang, Quantum computation and quantum information, Cambridge University Press 2010
2. Thomas H. Cormen Charles E. Leiserson Ronald L. Rivest Clifford Stein, Introduction to Algorithms, Second Edition, The MIT Press, Cambridge, Massachusetts

Reference papers

1. Robert S. Smith, Michael J. Curtis, William J. Zeng. A Practical Quantum Instruction Set Architecture. arXiv:1608.03355. 2016.
2. Eric C. Peterson, Gavin E. Crooks, Robert S. Smith. Fixed-Depth Two-Qubit Circuits and the Monodromy Polytope. arXiv:1904.10541. 2019.
3. Robert S. Smith. Someone Shouts |01000> !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 OUTCOMES:

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.

QT 611: QUANTUM TECHNOLOGY LABORATORY-II

SYLLABUS:

Sl. No.	**Name of experiments**
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.

QT 621: CLASSICAL AND QUANTUM CRYPTOGRAPHY

SYLLABUS:

Unit	Syllabus Details
Unit I	**Introduction to Post Quantum Cryptography:** What Is Post-Quantum Cryptography? Comparison to Quantum Cryptography. Introduction to Mathematics of Cryptography. Classical Cryptography.
Unit II	**Hash Based Digital Signature Schemes:** Hash Based One-Time Signature Schemes, Merkle's Tree Authentication Scheme, One-Time Key-Pair Generation Using an PRNG, Authentication Path Computation, Tree Chaining, Security In Merkle Signature Scheme.
Unit III	**Code-Based Cryptography:** Introduction to Code-Based Cryptography, Codes and Structures, McEliece Cryptosystem.
Unit IV	**Lattice Based Cryptography:** Introduction, Preliminaries of Linear 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.

Text Book

1. Post-Quantum Cryptography by Daniel J. Bernstein, Johannes, Buchmann, Erik Dahmen, Springer. ISBN: 978-3-540-88701-0.

Reference Books/Papers

1. Regev, O. 2009. School of Computer Science Tel Aviv University. Lattices in Computer Science 0368.4282. Lectures- 1, 2, 6.5.
2. Schneier, B. 1996. Applied Cryptography. John Wiley & Sons, Inc. ISBN: 0471128457
3. Research papers/Articles as required

COURSE OUTCOMES:

CO-1	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

QT 622: NONLINEAR AND QUANTUM OPTICS

SYLLABUS:

Unit	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
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 bunching and 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.

<u>Text/References</u>

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 OUTCOMES:

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

QT 623: MACHINE LEARNING

SYLLABUS:

Unit	Syllabus Details
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.

<u>Text / References</u>

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

COURSE OUTCOMES:

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

PGC-602: AUDIT COURSE

SYLLABUS:

Unit	Syllabus Details
Unit I	English for Research Paper Writing
Unit II	Disaster Management
Unit III	Sanskrit for Technical Knowledge

Unit IV	Value Education
Unit V	Constitution of India
Unit VI	Pedagogy Studies
Unit VII	Stress Management by Yoga
Unit VIII	Personality Development through Life Enlightenment Skills

M.TECH. IN TECHNOLOGY MANAGEMENT

SEMESTER I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	TM601	Introduction to Technology Management	3	1	4
2	TM602	R&D Management	3	1	4
3	TM603	Project Management	3	1	4
4	TM604	Strategic Management for Technology	3	1	4
5	TM605	Management of Innovation and Intellectual Property	3	1	4
6	TM615	Human Resource Management for Technology intensive organisations	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	TM610	Leadership & Organisational Behaviour	3	1	4
2	TM612	Quality Management	3	1	4
3	AM634	Applied statistics for Management	3	1	4
4	TM617	Logistics and Supply Chain Management	3	1	4
5		Elective – III	3	1	4
6		Elective – IV	3	1	4
7	PGC-602	Audit Course	2	0	2
		Total	**20**	**6**	**26**

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**

List of Electives:

Sl. No.	Course Code	Course Name
Elective I, II, III, IV, V & VI		
ELECTIVES FROM DEPARTMENT (Semester 2)		
1	TM607	Management of Manufacturing and Integration
2	TM608	Knowledge Management
3	TM609	System Engineering for Managers
4	TM611	Software Projects Management
5	TM613	Value Engineering
6	TM614	Design Management
7	TM616	Introduction to variables of Nation Building
8	TM618	Operations Management
9	TM619	Advanced Project Management Techniques
10	TM620	Accounting and Finance for Technologists
11	TM621	Artificial Intelligence (AI) for Managers
ELECTIVES FROM OTHER DEPARTMENT		
11		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.

SEMESTER 1 : INTRODUCTION TO TECHNOLOGY MANAGEMENT (TM601)

Course Outcomes	
CO -1	Understand the issue around Technology management, Technology Cycle and wealth creation through technological development.
CO -2	Identify the technology decisions for push-pull, assessments, strategy.
CO -3	Understanding the process of Technology planning, forecasting, road-mapping, transfer, acquisition, exploitation.
CO -4	To analyze Key current technological issues for organizations sustenance and transferring technology lab to land.

Unit	**Syllabus**
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).

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

SEMESTER 1 : R & D MANAGEMENT (TM 602)

Course Outcomes	
CO -1	To learn about leading R&D professionals; To gain insights about building effective R&D teams; To understand issues related to design of performance management and compensation management practices of R&D departments and organizations
CO -2	To learn about strategic management and issues related to commercialization of innovation (products, services) designed by R&D departments; To learn about innovative organizational design and issues related to knowledge management architectures
CO -3	To understand issues related to management of R&D projects (i.e., managing projects that are inherently risky and uncertain)
CO -4	To familiarize participants with basics of accounting and managing finances for risky and uncertain projects; and to gain a holistic understanding of issues related to management of creative talent within organizations

Unit	**Syllabus**
Unit I	Introduction to R&D function, The Strategic Aspects of R&D Management, Project Planning and Budgeting, R & D Road mapping, Project Selection, Project Evaluation. R&D- Marketing interface, Emerging Perspectives in Industrial R&D, External Technology Acquisition
Unit II	Human Resource Management in R&D, HR Planning, Attraction and Retention of Talent in R&D, Creativity in R&D Organizations, Interpersonal Relationships, Teams and Team building, Reward System, Performance Appraisal system and Career Management System
Unit III	New Product Development: What is New Product Development and why is it so important, The new Product Development Process Principles of Success, Phases of New Product Development, Idea Generation, Opportunity identification/selection Techniques, The New Product Process: The Stage-Gate, Frameworks for stakeholder involvement in NPD, Concurrent Engineering, Brand/value creation, Product Launch.

Text Books:

1. Hawthrone E.P., Management of Technology, McGraw-Hill, 1978.
2. Akhilesh KB, R&D Management, Springer, 2013
3. The Reflective Practitioner D.A. Schone Basic Books, NY, 1982
4. R&D Tactics H.R. Kaufman Front Range Research, Fort Collins, 1989

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

SEMESTER 1 : PROJECT MANAGEMENT (TM 603)

Course Outcomes	
CO -1	To recognize key factors in projects and project stages, cycle and responsibilities.
CO -2	To identify risk associated with project, its dynamics and team requirements for successfulness.
CO -3	To align the project activities through project network techniques and scheduling and its cost-time tradeoffs.
CO -4	Assessing the budget allocation/ financing issues, project handling and implementations through various case studies

Unit	Syllabus
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. 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	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. Software Packages application for Project Systems Management. Case studies

Text Books:

1. Iyer, P.P., Engineering Project Management with Case Studies, Vikas Publishing, New Delhi, 2009.
2. J.R., and Mantel, S.J. Jr., Project Management: A Managerial Approach, John Wiley and Sons, NY, 1995.
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 Gautam V. Desai, Project management: The Managerial Process (Sixth Edition), Mc Graw Hill Education (2014).

3. Project Management Institute, USA. A Guide to the Project Management Body of Knowledge. Newton Square, PA. 1996.
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

SEMESTER 1 : STRATEGIC MANAGEMENT FOR TECHNOLOGY (TM604)

Course Outcomes	
CO -1	Describe the practical and integrative model of strategic management process that defines basic activities in strategic management
CO -2	Demonstrate the knowledge and abilities in formulating strategies and strategic plans
CO -3	Analyze the competitive situation and strategic dilemma in dealing with dynamic global business environment in terms of rapidly changing market trends and technological advancement
CO -4	Evaluate challenges faced by managers in implementing and evaluating strategies based on the nature of business, industry, and cultural differences

Unit	Syllabus
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 in Strategic Management: 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.

Texts 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*

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

SEMESTER 1: MANAGEMENT OF INNOVATION AND INTELLECTUAL PROPERTY (TM605)

Course Outcomes	
CO -1	Different types of IP, Commercialization of IP, Intellectual property
CO -2	Industrial design, how to register at the right time, and privacy, Innovation management, geographical indication, and the trade secret
CO -3	Patent and who is the owner of the patent, as well as patent filling techniques
CO -4	Copyright, its ownership, and registering a creative work, Trademark involved and registration

Unit	**Syllabus**
Unit I	*Organizational and technological innovation* : role of organizational design and processes in managing inventions and innovations, introduction to intellectual property rights, strategic role of intellectual property protection in technological innovations case studies, role of open source, the use of patent information, the R&D value chain, stage gates , differences in priority with the R&D value chain
Unit II	*The Process of Technological Innovation*, Need for innovation in business: measuring innovative performance, Characteristics of innovative work environment, Stimulating Innovation, Promoting break through innovation, Open innovation and Knowledge Markets
Unit III	*Innovative inventions*: Commercial potential, management of processes to enhance innovative patents and technological know-how transfer, incubators, assessing patent value implications on managing the R&D value chain for corporate R&D, designing innovation and intellectual property divisions, and information technology support systems in managing innovation and intellectual property

Texts/References:

1. Trott, P., Innovation Management and New Product Development, Financial Times, Pitman Publishing, GB, 1998.
2. Joe Tidd & John R. Bessant , Managing Innovation: Integrating Technological, Market and Organizational Change, 7th Edition, Wiley
3. Shlomo Maital, Innovation Management: Strategies, Concepts and Tools for Growth and Profit, Sage Publishers
4. Anurag K. Agarwal, Business And Intellectual Property, Penguin Random House

5. Dr. Mathew Thomas,Understanding Intellectual Property, Eastern book company
6. https://www.amazon.com/How-Innovation-Works-Flourishes-Freedom/dp/0062916599

SEMESTER 1: HUMAN RESOURCE MANAGEMENT FOR TECHNOLOGY INTENSIVE ORGANISATIONS (TM 615)

Course Outcomes	
CO -1	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
CO -2	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
CO -3	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
CO -4	Be able to evaluate HRM related social, cultural, ethical and environmental responsibilities and issues in a global context

Unit	**Syllabus**
Unit I	Introduction, Personnel Management & HRM, elements & model, functions, challenges; Balanced Scorecard: history, perspectives, BSC & Strategy, Competency Management: Concept, need, competence & competency, framework.
Unit II	Cross Culture: nature, Hofstede's cultural dimensions, strategy; HR Audit: need, concept, strategy, structure, role of HRD audit, functions, methodology; Human capital and performance: 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.

Text Books:

1. Aswathappa, Human Resource Management: Text and Cases.
2. V. S. P. Rao, Human Resource Management, 2010.
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

References 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

SEMESTER 2 : LEADERSHIP & ORGANISATIONAL BEHAVIOUR (TM610)

Course Outcomes	
CO -1	**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**
CO -2	**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**
CO -3	**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**
CO -4	**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**

Unit	Syllabus
Unit I	Organisation: context, structure, processes, Theories of organisation, organisation and its environment, organisational analysis: Individual and Group, Organisational change and development.
Unit II	Functions of Human Resource Management, Recruitment, Selection, Performance Management, Reward and Compensation Management, Training and development, administration wage and salary, labour legislations and Industrial Relations.
Unit III	Basics of Human Behaviour, Leadership, Competing for the future through leadership management, career management and leadership pipeline, succession planning and change management.

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

References 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

SEMESTER 2 : QUALITY MANAGEMENT (TM 612)

Course Outcomes	
CO -1	To learn quality related issue and quality philosophies
CO -2	Usefulness of tools and techniques of seven quality control.
CO -3	Application of Quality six sigma approach with DMAIC phases, FMEA and QFD for benchmarking.
CO -4	Strategies for achieving incremental quality process through innovative problem solving approach and maintaining quality standards.

Unit	**Syllabus**
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; 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.

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.

SEMESTER 2 : APPLIED STATISTICS FOR MANAGEMENT (AM634)

Course Outcomes	
CO -1	Describe and discuss the key terminology, concepts tools and techniques used in business statistical analysis
CO -2	Critically evaluate the underlying assumptions of analysis tools
CO -3	Understand and critically discuss the issues surrounding sampling and significance
CO -4	Discuss critically the uses and limitations of statistical analysis
CO -5	Solve a range of problems using the techniques covered
CO -6	Conduct basic statistical analysis of data.

Unit	**Syllabus**
Unit I	*Nature and role of statistics for management:* Types of data, data measurement scales, Descriptive Statistics: Measures of Central Tendency, Measures of Dispersion, Introduction to probability theory. Probability Theory: Preliminary concepts in Probability, Basic Theorems and rules for dependent/independent events, Random Variable, Probability distributions, Sampling Techniques, Sampling distributions.
Unit II	*Hypothesis testing*: Z-test, t-test, Basic Two-Level Factorial Experiments, Additional Tools for Design and Analysis of Two Level Factorials, Correlation and Regression analysis, Multiple and Partial Correlation, ANOVA, Chi-square tests.
Unit III	Factor Analysis, Time Series Analysis and Business Forecasting, Non-Parametric Methods, SPSS and their use for statistical modeling, applications and case studies in data analysis,Excel,Minitab,R.

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. S C Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons (2014)
3. 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)

SEMESTER 2 : LOGISTICS AND SUPPLY CHAIN MANAGEMENT (TM617)

Course Outcomes	
CO -1	Understand the concept of Logistics, supply chain flows and drivers
CO -2	Learn Supply chain integration and process view for supply chain strategies.
CO -3	Advanced tools for managing supply chains through VMI, EDI, E-commers, centralized-decentralized process.
CO -4	Outsourcing, bidding, negotiation, procurement procedures through case studies of various companies.

Unit	Syllabus
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
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.

Text Books:

1. Simchi-Levi, D., Kaminsky, P., Simchi-Levi, E., and Ravi Shankar, Designing & Managing the Supply Chain: Concepts, Strategies & Case Studies, Third Edition, McGraw-Hill Publishing Company Ltd, New Delhi (2008)
2. Richard B. Chase, Ravi Shankar, and F. Robert Jacobs: Operations & Supply Chain Management (14th Edition), McGraw-Hill Publishing Company Ltd, New Delhi (2014)

Reference Books:

1. Chopra, S., Meindl, P. and Kalra DV, Supply chain Management: Strategy, Planning and Operations. Sixth Edition, Pearson Education (2016)
2. Tersine, R.J. Principles of Inventory and Materials Management, 4^{th} edition, Prentice-Hall Inc., New Jersey, (1994)

ELECTIVES FROM DEPARTMENT

MANAGEMENT OF MANUFACTURING AND INTEGRATION (TM 607)

Course Outcomes	
CO -1	To compete for the future through human resource management and organizational behavior concepts.

CO -2	To acquire knowledge of changing role of Managerial leadership leads to managing high risk in handling technology and building high performance teams.
CO -3	To understand the critical-to-quality concepts to increase overall productivity. To learn quality related issue and quality philosophies.
CO -4	To drive the economy for R&D activities through strategic aspects. To provide the strategies to mitigate cost and time overrun.
CO -5	To study the role of management of manufacturing and integration for working towards industry 4.0.

Unit	**Syllabus**
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.
Unit III	Flexible 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, Manufacturing 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

References 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

KNOWLEDGE MANAGEMENT (TM 608)

Course Outcomes	
CO -1	Understand Apply complex theories and practice of knowledge and intellectual capital management
CO -2	Understand Apply theories to a wide range of scenarios

CO -3	Formulate action plans for knowledge intensive organisations
CO -4	Distinguish aspects of industrial era management that may be inappropriate for knowledge intensive organisations and provide alternatives
CO -5	Understand Formulate a framework for thinking about knowledge intensive organisations
CO -6	Understand, describe and work with intangibles

Unit	**Syllabus**
Unit I	Data Information Knowledge wisdom, Knowledge cycle, Basics of Knowledge Management: Knowledge capture, storage, use and reuse learning organisations.
Unit II	Intellectual capital and its measurements, Performance management systems in Knowledge Management, Knowledge transfer in organisations, knowledge mapping, knowledge ownership, knowledge losses, knowledge management for new product development, Human aspects of knowledge management, design and implementation of effective knowledge management systems
Unit III	Knowledge Management in the Fourth Industrial Revolution, Theoretical and Practical Considerations in Cyber Physical Production Systems, the future of Knowledge Management

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 in Theory and Practice – Kimiz Dalkir
7. Knowledge Management – Shelda Debowski
8. Knowledge Management: Concepts and Best Practices by Kai Mertins (Editor), Peter Heisig (Editor), Jens Vorbeck (Editor)

References 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

SYSTEMS ENGINEERING FOR MANAGERS (TM 609)

Course Outcomes	
CO -1	Understand engineering design and product lifecycles in the context of the professional career Explain how system engineering methodologies make for an orderly design process

CO -2	Elaborate on how intended use guides the development of socio-technical systems, Develop and evaluate systems requirements
CO -3	Analyse and decompose system requirements into functions and design requirements, Plan the design process
CO -4	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
CO -5	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.

Unit	**Syllabus**
Unit I	SYSTEMS ENGINEERING AND THE WORLD OF MODERN SYSTEMS What Is 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

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

References 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

SOFTWARE PROJECTS MANAGEMENT (TM611)

Course Outcomes	
CO -1	Get an overview of Software project management, its evaluation, management and approach. Learn the concept of Agile Project Management.
CO -2	Calculate the software effort estimation through various methods.
CO -3	Determine the Project management scheduling through activities, Risk associated and resource association.
CO -4	Monitoring and control of overall project for assessing the project successfulness.
CO -5	Understanding software quality and reliability concept and its certification.

Unit	**Syllabus**
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.

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.

References 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.

VALUE ENGINEERING (TM 613)

Course Outcomes	
CO -1	Reference to acquire the basic concept of value engineering and value analysis.
CO -2	It gives functional approach to value improvement and various techniques of the job plan.
CO -3	Illustrations and In depth concept of life cycle costing and its methods.0
CO -4	Enriching value to the system through cognition and creativity and its usefulness.
CO -5	Evaluation of various value enrichment alternatives and making decision through matrix.

Unit	**Syllabus**
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.

Text Books:

1. Anil Kumar Mukhopadhyaya, Value Engineering: Concepts, Techniques and Applications, Sage Publication.
2. Zimmerman L., Value Engineering Paperback – 2010.

References Books:

1. Del l. Younker, Value Engineering: Analysis And Methodology,
2. J. Paul Guyer, Value Engineering (Engineering Sound Bites) Kindle Edition

DESIGN MANAGEMENT (TM 614)

Course Outcomes	
CO -1	Understand the various issues in philosophical and psychological perspectives.
CO -2	Developing design perceptions and its effect on competitiveness.
CO -3	Learn data elicitation techniques and various analysis useful for design management.
CO -4	Understanding the design thinking, value analysis and value engineering.
CO -5	Various applications of computer in design management. Exploring the knowledge on prototyping, entrepreneur and IPR.

Unit	**Syllabus**
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

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

References Books:

1. Michel Farr, Design Management.
2. Rachel Cooper, Sabine Junginger and Thomas Lockwood, Design Management.

INTRODUCTION TO VARIABLES OF NATION BUILDING (TM 616)

Course Outcomes	
CO -1	Evolution, basic concept and structure of National service scheme.
CO -2	Problem solving and decision making approach for improvement of life competencies.
CO -3	This guides for entrepreneurship development ways and means.

Unit	**Syllabus**
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.

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

References 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

OPERATIONS MANAGEMENT (TM618)

Course Outcomes	
CO -1	Understanding production and operations systems for manufacturing industry.
CO -2	Learning various tools and techniques for facilities planning and design.
CO -3	Various techniques for productions and management of inventory concept.

CO -4	Learning the concept of work study, time study, quality engineering, SPC and Maintenance concepts.
CO -5	Exploring world class manufacturing facilities and their practices as case study.

Unit	**Syllabus**
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, Value Engineering, Total quality &statistical process control. Maintenance management and equipment policies. Network planning and control. Line of Balance, World class manufacturing and factories of the future, Case studies.

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. Richard B. Chase, Ravi Shankar, and F. Robert Jacobs: Operations & Supply Chain Management (14th Edition), McGraw-Hill Publishing Company Ltd, New Delhi (2014)
2. Operations Management; J. Heizer and B. Render; 11th edition, Pearson.
3. Operations Management; Russell and Taylor; 7th edition, Wiley.

<u>ADVANCED PROJECT MANAGEMENT TECHNIQUES (TM619)</u>

Course Outcomes	
CO -1	To get awareness of various advanced project management concepts.
CO -2	Exploring software project management and tools and techniques for managing projects.
CO -3	Design and Development of product process and intricacies in project phases.
CO -4	The process of collaboration for product development and integration process.
CO -5	Various case studies and projects from different industries as applications of project management concept.

Unit	**Syllabus**
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.

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.

References 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

ACCOUNTING AND FINANCE FOR TECHNOLOGISTS (TM 620)

Course Outcomes	
CO -1	Understand the basic concepts of accounting and finance. Understanding the process of financing the projects, feasibility and funding.
CO -2	Acquire the knowledge on social cost benefit analysis, ROI, capita, audit and profit concepts.
CO -3	Focusing on contracts, cost escalation and its consequence.
CO -4	Determine Planning and budgeting for projects and its implication on it.
CO -5	Risk analysis of accounting and financing while import and export of product and projects and its case studies.

Unit	**Syllabus**
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

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.

ARTIFICIAL INTELLIGENCE (AI) FOR MANAGERS (TM621)

Course Outcomes	
CO -1	Develop a core understanding of AI & ML concepts and its business applications across sectors
CO -2	Gain exposure to the latest algorithms, tools, techniques, and frameworks used in AI & ML for solving real-world business challenges
CO -3	Explore the impact of these technologies on business outcomes across functions and domains
CO -4	Understand data and how AI & ML can be leveraged to create a data-driven organisation
CO -5	Gain hands-on learning in identifying, defining, designing, implementing & monitoring AI& ML Projects

Unit	**Syllabus**
Unit I	Information Systems, Introduction, Management of Information Systems, Types of Information Systems, Role of Data mining, Designing & Induction Challenges
Unit II	Artificial Intelligence Concepts, Different Types of AI – Narrow AI, General AI, Super AI, Building Blocks of AI, Basic Terminologies in AI&ML, Difference between AI, ML, DL, RL, BDA; ***Fields of AI*** – Computer Vision, Speech Analytics, Natural Language Processing ***AI Learning Models*** – Supervised, Unsupervised, Reinforcement
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 ***(A) Data and Algorithm*** Problems and required Algorithms Artificial Neural Network Big Data Analytics and AI

	(B) Develop AI & ML Models without writing code ***(C) AI Applications*** i. Computer Vision ii. Natural Language Processing **iii.** Voice AI
Unit IV	Developing Use Cases; Common Mis-conceptions about AI&ML Case studies/Tutorial on Application of AI for Management Decision

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. 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

PGC-601 – RESEARCH METHODOLOGY AND IPR

CO-1	Understanding the fundamentals of research and its methodology
CO-2	Choose the appropriate research design and develop appropriate research hypothesis for a research project
CO-3	Knowledge of manuscript preparation, patents and Intellectual property
CO-4	Technology transfer and application of IPR in various domains

Unit	Syllabus Details

Unit I	Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations
Unit II	Effective literature studies approaches, analysis Plagiarism, Research ethics,
Unit III	Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee
Unit IV	Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.
Unit V	Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications
Unit VI	New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

References Textbooks:

51. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for
52. science & engineering students'"
53. Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
54. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
55. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.
56. Mayall, "Industrial Design", McGraw Hill, 1992.
57. Niebel, "Product Design", McGraw Hill, 1974.
58. Asimov, "Introduction to Design", Prentice Hall, 1962.
59. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
60. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

PGC-602: AUDIT COURSE

CO-1	Understand that how to improve your writing skills and level of readability. Learn about what to write in each section. Understand the skills needed when writing a Title. Ensure the good quality of paper at very first-time submission.
CO-2	Understanding foundations of hazards, disasters and associated natural/social phenomena. Familiarity with disaster management theory (cycle, phases)
CO-3	Understanding basic Sanskrit language Ancient Sanskrit literature about science & technology can be understood Being a logical language will help to develop logic in students Discuss the growth of the demand for civil rights in India for the bulk of Indians before the arrival of Gandhi in Indian politics. Discuss the intellectual origins of the framework of argument that informed the

	conceptualization of social reforms leading to revolution in India.
CO-4	Students will gain deeper understanding about the purpose of their life. Students will understand and start applying the essential steps to become good leaders. Students will emerge as responsible citizens with clear conviction to practice values and ethics in life
CO-5	Demonstrate a broad and coherent body of knowledge with depth in the underlying principles and concepts. Integrate knowledge of the diversity of cultures and peoples. Use the collaborative learning into a course in a way that aligns with students learning objectives and intended outcomes. Critically analyse the classroom teaching learning and the ability to observe classroom behaviour.
CO-6	Use practical tools for stress management in educational environments; Foster resilience and cope with stressful situations at the workplace to increase their well-being; Improve their emotional intelligence to better deal with stress; Understand the best relaxation techniques for educators and students
CO-7	p inter personal skills and be an effective goal-oriented team player. p professionals with idealistic, practical and moral values. p communication and problem-solving skills. neer attitude and understand its influence on behavior

Unit	Syllabus Details
Unit I	**English for Research Paper Writing** Planning and preparation, identifying research problem, research questions, structuring paragraph, developing a persuasive style in writing, objectivity, avoiding ambiguity etc. Methodology, literature review/survey, writing introduction, result discussion, analyzing findings, conclusion and various sections.
Unit II	**Disaster Management** Introduction: Concepts and definitions: Disaster, hazard, vulnerability, resilience, risks, frequency and details, capacity, impact, prevention, mitigation. Disaster Risk Reduction (DRR) Disaster management: Applications and case studies
Unit III	**Sanskrit for Technical Knowledge** Alphabets in Sanskrit, Past/Present/Future Tense, Simple Sentences Technical information about Sanskrit Literature Technical concepts of Engineering-Electrical, Mechanical, Architecture, Mathematics

Unit IV	**Value Education** Values and self-development Personality and Behavior Development Character and Competence
Unit V	**Constitution of India** History of Making of the Indian Constitution Philosophy of the Indian Constitution Contours of Constitutional Rights & Duties Organs of Governance Local Administration Election Commission
Unit VI	**Pedagogy Studies** Introduction and Methodology : Aims and rationale, Policy background, Conceptual framework and terminology Thematic overview: Pedagogical practices are being used by teachers in formal and informal classrooms in developing countries. Evidence on the effectiveness of pedagogical practices :Professional development: alignment with classroom practices and follow-up support
Unit VII	**Stress Management by Yoga** Definitions of Eight parts of yoga.(Ashtanga) Yam and Niyam. Do`s and Don't's in life. Asan and Pranayam
Unit VIII	**Personality Development through Life Enlightenment Skills** Holistic development of personality Approach to day to day work and duties

<u>Text Books:</u>

1. Goldbort R *Writing for Science*, Yale University Press (available on Google books): 2006
2. Day R: *How to write and Publish a Scientific Paper*, Cambridge University Press :2006
3. Adrian Wallwork, *English for Writing Research Papers*, Springer New York, 2011
4. Chakroborty, S.K. "Values and Ethics for organizations Theory and practice", Oxford University Press, New Delhi
5. Tushar Bhattacharya, "Disaster Science and Management", McGraw Hill India Education Pvt. Ltd., 2012.
6. Pradeep Sahni, "Disaster Mitigation: Experiences and Reflections", Prentice Hall,2004.
7. Singhal J.P. "Disaster Management", Laxmi Publications, 2010.
8. Donald Hyndman & David Hyndman, "Natural Hazards & Disasters", Cengage Learning, 2010.
9. Singh B.K., Handbook of Disaster Management: Techniques & Guidelines, Rajat Publication, 2008.
10. Govt. of India: Disaster Management Act, Government of India, New Delhi, 2005.
11. 'Yogic Asanas for Group Training-Part-I":Janardan Swami Yogabhyasi Mandal, Nagpur
12. "Rajayoga or conquering the Internal Nature" by Swami Vivekananda, Advaita Ashrama (Publication Department), Kolkata

Reference books:

1. S.C. Parja & Vikram Kate. *Writing and Publishing a Scientific Research Paper*. Springer: 2017.
2. Highman N, *Handbook of Writing for the Mathematical Sciences*, Highman's Book: 1998.
3. "Abhyaspustakam" – Dr.Vishwas, Samskrita-Bharti Publication, New Delhi
4. "Teach Yourself Sanskrit" Prathama Deeksha-VempatiKutumbshastri, Rashtriya Sanskrit Sansthanam, New Delhi Publication
5. "India's Glorious Scientific Tradition" Suresh Soni, Ocean books (P) Ltd., New Delhi.
6. The Constitution of India, 1950 (Bare Act), Government Publication.
7. Dr. S. N. Busi, Dr. B. R. Ambedkar framing of Indian Constitution, 1st Edition, 2015.
8. M. P. Jain, Indian Constitution Law, 7th Edn., Lexis Nexis, 2014.
9. D.D. Basu, Introduction to the Constitution of India, Lexis Nexis, 2015
10. Ackers J, Hardman F (2001) Classroom interaction in Kenyan primary schools, Compare, 31 (2): 245-261.
11. Agrawal M (2004) Curricular reform in schools: The importance of evaluation, Journal of Curriculum Studies, 36 (3): 361-379.
12. Alexander RJ (2001) Culture and pedagogy: International comparisons in primary education. Oxford and Boston: Blackwell.

DEPT OF ELECTRONICS ENGG

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.	EE601	Microwave Engineering	3	1	4
2.	EE602	Digital Signal Processing	3	1	4
3.	EE603	Wireless and Mobile Communication	3	1	4
4.	EE604	Radar System Design	3	1	4
5.	EE624	Digital System Design using FPGA	3	1	4
6.	AM607	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	EE606	Statistical Signal Processing	3	1	4
2	EE607	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	Audit 1 and 2	2	0	0
		Total	20	6	24

* 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	EE651	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	EE652	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.	EE601	Microwave Engineering	3	1	4
2.	EE602	Digital Signal Processing	3	1	4
3.	EE603	Wireless and Mobile Communication	3	1	4
4.	EE604	Radar System Design	3	1	4
5.	EE624	Digital System Design using FPGA	3	1	4
6.	AM607	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	EE610	Radar Signal Processing	3	1	4
2	EE611	Array Signal Processing	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	Audit 1 and 2	2	0	0
		Total	20	6	24

* 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	EE651	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	EE652	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.	EE601	Microwave Engineering	3	1	4
2.	EE602	Digital Signal Processing	3	1	4
3.	EE603	Wireless and Mobile Communication	3	1	4
4.	EE604	Radar System Design	3	1	4
5.	EE624	Digital System Design using FPGA	3	1	4
6.	AM607	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	EE609	Antenna Systems	3	1	4
2	EE614	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	Audit 1 and 2	2	0	0
		Total	20	6	24

*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	EE651	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	EE652	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.	EE602	Digital Signal Processing	3	1	4
2.	EE621	Digital IC Design	3	1	4
3.	EE622	RF IC Design	3	1	4
4.	EE650	Semiconductor devices for high speed and high power applications	3	1	4
5.	EE624	Digital System Design using FPGA	3	1	4
6.	AM607	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.	EE638	Analog and Mixed mode VLSI Design	3	1	4
2.	EE648	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	Audit 1 and 2	2	0	0
		Total	20	6	24

Semester III (@ NIELIT CALICUT)

Sl. No	Course Code	Course Title	Contact Hours /week		*Credits
			L	T/P	
1	EE651	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	EE652	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	EE605	Navigation System Concepts	3	1	4
2	EE608	Modern Wireless Communications	3	1	1
3	EE612	High Power Microwave Systems	3	1	4
4	EE613	Electronic Warfare	3	1	4
5	EE619	Software Defined Radio	3	1	4
6	EE620	SoC and Embedded Systems	3	1	4
7	EE623	Semiconductor Devices	3	1	4
8	EE625	High Performance DSP using FPGA	3	1	4

9	EE626	Compressed Sensing & Sparse Signal Processing	3	1	4
10	EE627	Signal Theory, Linear Algebra & Transform Techniques	3	1	4
11	EE628	Advanced Electronics Systems	3	1	4
12	EE629	Sonar Signal Processing	3	1	4
13	EE630	Sonar System Engineering	3	1	4
14	EE631	Satellite Communication	3	1	4
15	EE632	Advanced Communication Systems	3	1	4
16	EE633	Underwater Communications	3	1	4
17	EE634	Monolithic Microwave Integrated Circuit	3	1	4
18	EE635	Inertial Sensors and Systems	3	1	4
19	EE636	Navigation & Avionic Systems	3	1	4
20	EE637	ASIC Verification using System Verilog	3	1	4
21	EE638	Analog and Mixed mode VLSI Design	3	1	4
22	EE639	Computer Aided Design for VLSI Circuits	3	1	4
23	EE640	FPGA Architecture and Applications	3	1	4
24	EE641	VLSI Signal Processing	3	1	4
25	EE642	SoC Design and Verification	3	1	4
26	EE643	Digital Interface Design	3	1	4
27	EE644	MIMO Communications	3	1	4
28	EE645	Advanced Digital Signal Processing	3	1	4
29	EE646	Advanced Simulation Techniques	3	1	4
30	EE647	RF Photonics	3	1	4
31	EE648	VLSI Fabrication Technology	3	1	4
32	EE649	Introduction to Electronics Systems	3	1	4
33	EE650	Semiconductor devices for high speed and high power applications	3	1	4
34	EE651	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	ents will be able to apply their knowledge and skills to simulate moving target)ARs, 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 Pd,
Probability of False Alarm PFA and Relation between Pd, Pfa 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**, t**he 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.BehzadRazavi, "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 a 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 : EE631

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.SuyderHond 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	Create SV based test environment for 1-bit adder. 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 specification. 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, Givens 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: EE651

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

Course Name: Research Methodology and IPR
Course Code: PGC601
Course Outcomes:

CO-1	Understanding the fundamentals of research and its methodology
CO-2	Choose the appropriate research design and develop appropriate research hypothesis for a research project
CO-3	Knowledge of manuscript preparation, patents and Intellectual property
CO-4	Technology transfer and application of IPR in various domains

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

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

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

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

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

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

References Textbooks:

61. Stuart Melville and Wayne Goddard, “Research methodology: an introduction for
62. science & engineering students’”
63. Wayne Goddard and Stuart Melville, “Research Methodology: An Introduction”
64. Ranjit Kumar, 2nd Edition, “Research Methodology: A Step by Step Guide for beginners”
65. Halbert, “Resisting Intellectual Property”, Taylor & Francis Ltd,2007.
66. Mayall, “Industrial Design”, McGraw Hill, 1992.
67. Niebel, “Product Design”, McGraw Hill, 1974.
68. Asimov, “Introduction to Design”, Prentice Hall, 1962.
69. Robert P. Merges, Peter S. Menell, Mark A. Lemley, “ Intellectual Property in New Technological Age”, 2016.
70. T. Ramappa, “Intellectual Property Rights Under WTO”, S. Chand, 2008

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 and Technology

Semester I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	NT-601	Introduction to Nano Science and 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	Nanotechnology in Devices	3	1	4
5	NT 605	Characterization of Nano Materials	3	1	4
6	MM-606	Introduction to 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 Defence Applications	3	1	4
2	AP-609	Advanced Sensors	3	1	4
3		Elective – I [From Dept. of Applied Chemistry/ Physics/Metallurgy and Materials Engg.]	3	1	4
4		Elective – II [From Dept. 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	Audit 1 and 2	2	0	0
		Total	**22**	**4**	**24**

- 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**

<u>List of Electives/ Self Study</u>

Sl. No.	Course Code	Course Name
1	MM 610	Nanomaterials and their applications
2	MM 612	Polymer Blends and Nanocomposites
3	AC 608	Safety Health and Hazard Management
4	AC 609	NBC Warfare (Concepts & Remediation)
5	ME 636	MEMS - Design, Fabrication, and Characterization
6	NT-607	Nanobiotechnology
7	AP-640	Nanophotonics
8	Electives from other Department, MOOC/NPTEL courses	

<u>Introduction to Nano Science and Technology (NT-601):</u>

- **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, crystalline, polycrystals, symmetry, Unit Cells, Crystal Structures (Bravais Lattices), Crystallographic Planes, Miller Indices, Brillouin, zones, Electronic Properties, Classification of materials: Metal, Semiconductor, Insulator, Band, structure.

- **UNIT III:** 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, tenability of properties, : Physical Chemistry of solid surfaces, crystal structures, surface energy, chemical potential, 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, quantum wells, metal nanostructures, nanofluids.

- **Text Books:**
  Pradeep, T., Nano: The Essentials, McGraw Hill Publishers, Mumbai, 2007.

- **References:**

  1. Charles P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology, John Wiley & Sons 2003.
  2. Vladimir V. Mitin, Viatcheslav A. Kochelap, Viacheslav Aleksandrovich Kochelap Introduction to Nanoelectronics: Science, Nanotechnology, Cambridge University – 2008
  3. Pignataro, B., Tomorrow's Chemistry Today–Concepts in Nano science, Organic Materials, andEnvironmental Chemistry, Wiley-VCH, Royal chemical society, 2008
  4. Howard, H., Into The Nano Era: Moore's Law Beyond Planar Silicon CMOS (Vol. 106), Springer Series in Materials Science, Springer-Verlag Berlin, 2004 .

Synthesis of Nanomaterials (NT-602):

- **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; Sonochemical 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.

- **References:**

  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, Nanostructures & Nanomaterials: Synthesis, Properties &Applications , Imperial College 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: fundamental and device applications, Cambridge University Press, 2001.

6. S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980.
7. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate(Eds.), Handbook of NanoScience, Engg. and Technology, CRC Press, 2002.

Nano-materials for Energy and Environmental Objectives (NT 603):

UNIT I :- INTRODUCTION
Sustainable energy -Materials for energy -Green house 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 and performance 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.

- **REFERENCES:**

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 and Energy ... · 2018.
3. Handbook of fuel cells: Fuel cell technology and applications by Vielstich. Wiley, CRC Press, 2003.
4. Hydrogen from Renewable Energy Sources by D. Infield 2004.
5. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.

Nanotechnology in Devices (NT 604):

UNIT I: Basics of Electronic Devices: Maxwell-Boltzmann and Fermi-Dirac distribution, doping, carrier transport mechanisms, - drift, diffusion, thermionic emission, and tunneling; excess carriers, carrier lifetime, recombination mechanisms – SHR, Auger, radiative, and surface. p-n junctions – fabrication, basic operation – forward and reverse bias, DC model, charge control model, IV characteristic, Working principle of BJT anf FET, effect of device size reduction,

UNIT II: Nanotechnology in electronic devices: Electron transport phenomenon at nanoscale dimensions, Single electron transistor, Organic electronic Devices, Recent devices, including FinFET, Tunnel FET, and emerging materials, including graphene, and its applications, spintronics

UNIT III: Quantum well structures in devices: Lasers, detectors, LEDs etc.

UNIT IV: Plasmonics: Evanescent waves, Surface Plasmon dispersion equations, resonance, excitation of surface plasmons, surface Plasmon properties, SPR spectroscopy, Applications of Plasmonics.

REFERENCES:

1. Donglu Shi, Nanomaterials and Devices, Elsevier, 2014
2. B.W.Mott, "Micro-Indentation Hardness Testing", Butterworths, London
3. M. H.Loretto, "Electron Beam Analysis of Materials", Chapman and Hall, 1984.

Characterization of Nanomaterials (NT-605):

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

UNIT III:- SPECTROSCOPIC TECHNIQUES

X ray Photon Spectroscopy, FTIR , Raman spectroscopy

UNIT IV: THERMAL ANALYSIS TECHNIQUES

DSC, DTA, and TGA

UNIT V: ADVANCED TECHNIQUES

Dyanamic Light Scattering, nanoindentation, VSM

- **Text/ 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, Springer Nature – 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.

Nanotechnology for Defence Applications (NT 606):

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: Nanomaterials in thermoelectric and piezoelectric sensing

Unit IV: Chemical and biological warfare: Nanomaterials in detection and decontamination of CW and BW agents

Unit V: Role of Nanotechnology in next generation Warfare: Precision guided munitions, miniaturized vehicles

References:

- Nanotechnology for Defence Applications, Narendra Kumar, Ambesh Dixit, Springer, 2019.
- Nanotechnology for Chemical and Biological Defense, Margaret Kosal · 2009, Springer
- Nanotechnology in the Defense Industry: Advances, Innovations and Practical Applications, Madhuri Sharon, Angelica S. L. Rodriguez, Chetna Sharon, Wiley, 2019.

Nanobiotechnology (NT 607)

UNIT I: Introduction, History & Applications 1) Various definitions and Concept of Nano-biotechnology & Historical background. 2) Fundamental sciences and broad areas of Nanobiotechnology. 3) Various applications of Nano-biotechnology 4) Cell – Nanostructure interactions

UNIT II: Biological nanoparticles production, surface functionalization- and their Applications plants and microorganism

Proteins, DNA based nanostructure

UNIT III: Devices based on nanobiotechnology – and their applications, lab on a chip.

UNIT IV: Applications of Nanotechnology in Drug: Discovery and Delivery, bioinformatics

References:

- Nanobiotechnology: A Multidisciplinary Field of Science, Basma A. Omran, 2020, Springer
- Nanobiotechnology: Concepts, Applications and Perspectives, Christof M. Niemeyer, Chad A. Mirkin · 2006, Wiley-VCH
- Microbial Nanobiotechnology: Principles and Applications, Agbaje Lateef, Evariste Bosco Gueguim-Kana, Nandita Dasgupta · 2021, Springer.

Nanophotonics (AP 640):

1. Electromagnetism in Mixed Dielectric Media
The Macroscopic Maxwell Equations, Electromagnetism as an Eigenvalue Problem, General Properties of the Harmonic Modes, Electromagnetic Energy and the Variational Principle, Magnetic vs. Electric Fields, Scaling Properties of the Maxwell Equations, Discrete vs. Continuous Frequency Ranges

2. Symmetries and Solid-State Electromagnetism
Using Symmetries to Classify Electromagnetic Modes, Continuous Translational Symmetry, Discrete Translational Symmetry, Photonic Band Structures, Rotational Symmetry and the Irreducible Brillouin Zone, Mirror Symmetry and the Separation of Modes, Time-Reversal Invariance

3. The Multilayer Film: The Multilayer Film, The Physical Origin of Photonic Band Gaps, The Size of the Band Gap, Evanescent Modes in Photonic Band Gaps , Off-Axis Propagation, Localized Modes at Defects, Surface States, Omnidirectional Multilayer Mirrors

4. Metamaterial: Definition, Negative-refractive Index materials, Metamaterials as perfect lens and cloaking objects. Geometries of metamaterials.

5. Plasmonics: Evanescent waves, Surface Plasmon dispersion equations, resonance, excitation of surface plasmons, surface Plasmon properties, SPR spectroscopy, Applications of Plasmonics.

- **REFERENCES**

1. Motoichi Ohtsu · 2011 Progress in Nanophotonics, Springer Heidelberg Dordrecht, London New York – 2011.
2. Hilmi Volkan Demir, Sergey V. Gaponenko Applied Nanophotonics, Cambridge University – 2019.

3. Paras N. Prasad · 2004 Nanophotonics, John Wiley & Sons – 2004.
4. Lucas Novotny and Bert Hecht, "Principles of Nano-Optics" ,Cambridge University Press, 2012.
5. Masuhara. H. Kawata. S and Tokunga. F ―NanoBiophotoics", Elsevier Science, 2007.
6. Saleh. B. E. A and Teich. A. C "Fundamentals of Photonics", John Wiley and Sons, NewYork,1993.
7. Prasad. P. N―Introduction to Biophotonics", John Wiley and Sons, 2003.

Ohtsu. M. Kobayashi. K. Kawazoe. T and Yatsui. T. ―Principals of Nanophotonics (Optics and Optoelectronics)" University of Tokyo, Japan, 2003

<u>Nanomaterial and Their Applications (MM 610):</u>

Unit 1: Overview of Nanostructures and Nanomaterials; Synthesis of Nanomaterials: Types and strategies for synthesis of nanomaterials;

Unit 2: 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 3: Cellsresponse to Nanostructures; Surfaces and interfaces in nanostructures, Ceramic interfaces, Super hydrophobic surfaces, Grain boundaries in Nanocrystalline materials, Defects associated with interfaces.

Unit 4: Thermodynamics of Nanomaterials; Overview of properties of nanostructures and nanomaterials; Overview of characterization of nanostructures and nanomaterials; Deformation behavior of nanomaterials: Fracture and creep;Nanomechanics and nano-tribology; Electrical, Magnetic and Optical properties;

Unit 5: Applications of Nanotechnology in various fields: Defence, Aerospace and Marine Nanotechnology, Renewable energy, solar energy, fuel cells, Reinforcement in Ceramics, Drug delivery, Electronics etc.

- **REFERENCES**

1 Olena Fesenko, Leonid Yatsenko Nanocomposites, Nanostructures, and Their Applications, Springer Nature Switzerland AG 2019.

2 Zishan Husain Khan, Nanomaterials and Their Applications, Springer Nature Springer Nature Singapore Pte Ltd. 2018.

M.Tech. in Materials Science and Chemical Technology (Materials Science and Technology)

SEMESTER I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	MM-601	Concepts in Metal and Ceramic	3	2	4
2	MM-602	Materials Characterization	3	2	4
3	MM-603	Thermodynamics of Materials	3	1	4
4	MM-604	Polymers and Composites Technology	3	1	4
5	MM-605	Physical and Mechanical Metallurgy	3	2	4
6	MM-606	Introduction to Computational Materials Engineering	3	1	4
7	PGC-601	Research Methodology and IPR	2	0	2
		Total	20	9	26

SEMESTER II

Sl. No.	**Course Code**	**Course**	**Contact Hours/week**		**Credits**
			L	T/P	
1	MM 607	Design of Materials	3	1	4
2	MM-608	Fatigue, Fracture and Failure Analysis	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	Audit Course	2	0	2
		Total	20	6	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 609	Materials Processing
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	Electrical and Electronic Materials
7	MM 615	Magnetism and Magnetic Materials
8	MM 616	Heat-treatment of Metals and alloys
9	MM 617	Materials for High -Temperature Applications
10	MM 618	Advanced Steel Technology
11	MM 619	Military 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 in Materials Science and Chemical Technology (Materials Science and Technology) 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 Science and Chemical Technology 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 Science and Chemical Technology 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 Photon 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:	Demonstrated 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
Unit V	Free energy of binary system: Entropy of mixing, Enthalpy of mixing, Free energy of ideal, regular and real solutions, Activity, Ordered and intermediate phases, Types of solutions, Chemical potential, Unary and binary phase diagrams and Gibbs free energy

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: Polymers 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
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: Introduction to 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 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: 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: Research Methodology and IPR
Course Code: PGC-601

Course Outcomes (CO):	
CO-1	Understanding the fundamentals of research and its methodology
CO-2	Choose the appropriate research design and develop appropriate research hypothesis for a research project
CO-3	Knowledge of manuscript preparation, patents and Intellectual property
CO-4	Technology transfer and application of IPR in various domains

	Syllabus Details
Unit I:	Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations
Unit II:	Effective literature studies approaches, analysis Plagiarism, Research ethics,
Unit III	Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee
Unit IV	Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.
Unit V	Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications
Unit VI	New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

References Textbooks:

- *Stuart Melville and Wayne Goddard, "Research methodology: an introduction for*
- *science & engineering students'"*
- *Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"*
- *Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for*
- *beginners"*
- *Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.*
- *Mayall, "Industrial Design", McGraw Hill, 1992.*
- *Niebel, "Product Design", McGraw Hill, 1974.*
- *Asimov, "Introduction to Design", Prentice Hall, 1962.*

- *Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.*
- *T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008*

Course Name: Audit Course
Course Code: PGC-602

	Syllabus Details
Unit I:	English for Research Paper Writing
Unit II:	Disaster Management
Unit III	Sanskrit for Technical Knowledge
Unit IV	Value Education
Unit V	Constitution of India
Unit VI	Pedagogy Studies
Unit VII	Stress Management by Yoga
Unit VIII	Personality Development through Life Enlightenment Skills

- **List of Electives:**

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 Joseph 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:	Elaborated the classification of biomaterials
CO-3:	Cognizance of Nano biomaterials
CO-4:	Projected 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, biofluidic 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: Electrical and Electronic Materials
Course Code: MM 614

Course Outcomes (CO):	
CO-1:	Understand electronic materials and their electrical characteristics
CO-2:	Recognize different semiconductors, their properties and pn junction band diagrams
CO-3:	Classification of supercapacitors along with materials used.
CO-4:	Learn dielectrics and types of capacitors based on it.
CO-5:	Applications of electric and electronic materials.

	Syllabus Details
Unit I	Band Theory of Solids, Semiconductors, Electron Effective Mass, Density of States in an Energy Band, Fermi-Dirac Statistics
Unit II	Intrinsic Semiconductors, Extrinsic Semiconductors, Temperature Dependence of Conductivity, Recombination and Minority Carriers, Continuity Equations, Optical Absorption, Ideal *pn* Junction and Band Diagram, Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET),
Unit III	Supercapacitors, Types of supercapacitor. Ceramic substrates (Al_2O_3, SiC, BeO, AlN, Glass ceramic etc.), Processing of Thick Film, Thin Film, Multi-layer Packages, Properties of Ceramic Insulators, Ceramic Capacitor
Unit IV	Dielectrics-Barium titanate, Other titanate based dielectrics, Composition with high Pb content, Processing of thick and thin film capacitors, Integrated capacitors
Unit V	Relaxor Dielectrics, Piezoelectric Ceramics and electrostrictive materials, Powders and Processes, Piezoelectric ceramic applications. Nano Ceramics: Different Compositions, Synthesis, Applications, Introduction to electric vehicle.

Textbooks

- *Materials for Electronics: R.C. Buchanon.*
- *Introduction to Ceramics: W.D. Kingery*
- *Fundamentals of Ceramics: Barsoum*

Reference Book(s):

- *Physical Ceramics for Engineers: VanVlack*
- *Handbook of Ceramics: Editor S. Kumar Ceramic*

- *Electronic Ceramics: B.C.H Steele.*
- *Adv. Ceram. Materl. Vol I by K Furuta & K U chino*

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:	Explored 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
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 pearlitic 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-Heinemann, 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 armour 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*

M.Tech. in Materials Science and Chemical Technology (Corrosion Technology)

SEMESTER I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	MM-601	Concepts in Metal and Ceramic	3	2	4
2	MM-602	Materials Characterization	3	2	4
3	MM 620	Introduction to Corrosion	3	1	4
4	MM 621	Welding Science and Technology	3	1	4
5	MM-605	Physical and Mechanical Metallurgy	3	2	4
6	MM-606	Introduction to Computational Materials Engineering	3	1	4
7	PGC-601	Research Methodology and IPR	2	0	2
		Total	20	9	26

SEMESTER II

Sl. No.	**Course Code**	**Course**	**Contact Hours/week**		**Credits**
			L	T/P	
1	MM 622	High temperature Corrosion	3	2	4
2	MM-623	Corrosion mitigation	3	1	4
3		Elective I (from Departmental Electives)	3	1	4
4		Elective II (from Departmental Electives)	3	1	4
5		Elective – III (from Open Electives)	3	1	4
6		Elective – IV (from Open Electives)	3	1	4
7	PGC-602	Audit Course	2	0	2
		Total	20	7	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

<u>List of Electives:</u>

Sr. No.	Course Code	Electives from the Department
1	MM 610	Nanomaterials and Their Applications
2	MM 607	Design of Materials
3	MM 608	Fatigue, Fracture, and Failure Analysis
4	MM 617	Materials for High temperature applications
5	MM 611	Non-Destructive Evaluations
6	MM 616	Heat treatment of Metals and alloys
7	MM 624	Advanced Coating
8	MM 625	Surface Science and Engineering
9	MM 612	Polymers Blends and Nanocomposites
10	MM 626	Reliability Engineering
11	MM 610	Nanomaterials and Their Applications

<u>Program Outcomes (POs)</u>

- **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 (Corrosion Technology) 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 Corrosion Technology 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 Science and Technology 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 in metals and ceramics
Unit II	Crystalline and non-crystalline metals and ceramics, anisotropy; Structure of crystalline solids: metallic and ceramic crystal structure
Unit III	Ceramic materials, Basic properties, classification of ceramic materials– conventional and advanced, 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	Mechanical properties of ceramics, toughening of ceramics, ceramics for wear resistance applications, Dielectrics: Dielectric strength, Loss factor. Equivalent circuit description of linear dielectrics, Power factor, Dielectric polarisation, Polarisation mechanisms, Ferroelectric and Piezoelectric ceramics, Magnetic ceramics, Applications- Refractories: Classification of Refractories, Applications. Glass: Definition of glass, Basic concepts of glass structure, Different types of glasses, Tempering 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 their 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 Photon Spectroscopy and Auger electron spectroscopy, UV-Vis and IR 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: 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*

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: Introduction to 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 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: Welding Science and Technology
Course Code: MM 621

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: Research Methodology and IPR
Course Code: PGC-601

Course Outcomes (CO):	
CO-1	Understanding the fundamentals of research and its methodology
CO-2	Choose the appropriate research design and develop appropriate research hypothesis for a research project
CO-3	Knowledge of manuscript preparation, patents and Intellectual property
CO-4	Technology transfer and application of IPR in various domains

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

Unit II:	Effective literature studies approaches, analysis Plagiarism, Research ethics,
Unit III	Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee
Unit IV	Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.
Unit V	Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications
Unit VI	New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

References Textbooks:

- *Stuart Melville and Wayne Goddard, "Research methodology: an introduction for*
- *science & engineering students'"*
- *Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"*
- *Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for*
- *beginners"*
- *Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.*
- *Mayall, "Industrial Design", McGraw Hill, 1992.*
- *Niebel, "Product Design", McGraw Hill, 1974.*
- *Asimov, "Introduction to Design", Prentice Hall, 1962.*
- *Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.*
- *T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008*

Course Name: Audit Course
Course Code: PGC-602

	Syllabus Details
Unit I:	English for Research Paper Writing
Unit II:	Disaster Management
Unit III	Sanskrit for Technical Knowledge
Unit IV	Value Education
Unit V	Constitution of India
Unit VI	Pedagogy Studies
Unit VII	Stress Management by Yoga
Unit VIII	Personality Development through Life Enlightenment Skills

Course 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.*

➢ **List of Electives:**

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; Agglomeration and Dispersion
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: 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: 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: Heat-treatment of Metals and Alloys
Course Code: MM 616

Course Outcomes (CO):	
CO-1:	Explored 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
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 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, 2003.*

M.Tech. in Materials Engineering

SEMESTER I

Sl. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	MM-601	Concepts in Metal and Ceramic	3	2	4
2	MM-602	Materials Characterization	3	2	4
3	MM-603	Thermodynamics of Materials	3	1	4
4	MM-604	Polymers and Composites Technology	3	1	4
5	MM-605	Physical and Mechanical Metallurgy	3	2	4
6	MM-606	Introduction to Computational Materials Engineering	3	1	4
7	PGC-601	Research Methodology and IPR	2	0	2
		Total	20	9	26

SEMESTER II

Sl. No.	**Course Code**	**Course**	**Contact Hours/week**		**Credits**
			L	T/P	
1	MM 619	Military Materials	3	1	4
2	MM-608	Fatigue, Fracture and Failure Analysis	3	1	4
3		Elective I (from Departmental Electives)	3	1	4
4		Elective II (from Departmental Electives)	3	1	4
5		Elective – III (from Open Electives)	3	1	4
6		Elective – IV (from Open Electives)	3	1	4
7	PGC-602	Audit Course	2	0	2
		Total	20	6	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 609	Materials Processing
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	Electrical and Electronic Materials
7	MM 615	Magnetism and Magnetic Materials
8	MM 616	Heat-treatment of Metals and alloys
9	MM 617	Materials for High -Temperature Applications
10	MM 618	Advanced Steel Technology
11	MM 607	Design of 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 Photon 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
Unit V	Free energy of binary system: Entropy of mixing, Enthalpy of mixing, Free energy of ideal, regular and real solutions, Activity, Ordered and intermediate phases, Types of solutions, Chemical potential, Unary and binary phase diagrams and Gibbs free energy

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
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: Introduction to 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 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: 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: 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: Research Methodology and IPR

Course Code: PGC-601

Course Outcomes (CO):	
CO-1	Understanding the fundamentals of research and its methodology
CO-2	Choose the appropriate research design and develop appropriate research hypothesis for a research project
CO-3	Knowledge of manuscript preparation, patents and Intellectual property
CO-4	Technology transfer and application of IPR in various domains

	Syllabus Details
Unit I:	Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations
Unit II:	Effective literature studies approaches, analysis Plagiarism, Research ethics,
Unit III	Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee
Unit IV	Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.
Unit V	Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications
Unit VI	New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

References Textbooks:

- *Stuart Melville and Wayne Goddard, "Research methodology: an introduction for*
- *science & engineering students'"*
- *Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"*
- *Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for*
- *beginners"*
- *Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd,2007.*
- *Mayall, "Industrial Design", McGraw Hill, 1992.*

- *Niebel, "Product Design", McGraw Hill, 1974.*
- *Asimov, "Introduction to Design", Prentice Hall, 1962.*
- *Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age", 2016.*
- *T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008*

Course Name: Audit Course
Course Code: PGC-602

	Syllabus Details
Unit I:	English for Research Paper Writing
Unit II:	Disaster Management
Unit III	Sanskrit for Technical Knowledge
Unit IV	Value Education
Unit V	Constitution of India
Unit VI	Pedagogy Studies
Unit VII	Stress Management by Yoga
Unit VIII	Personality Development through Life Enlightenment Skills

- **List of Electives:**

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: 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: Electrical and Electronic Materials
Course Code: MM 614

Course Outcomes (CO):	
CO-1:	Understand electronic materials and their electrical characteristics
CO-2:	Recognize different semiconductors, their properties and PN junction band diagrams
CO-3:	Classification of supercapacitors along with materials used.
CO-4:	Learn dielectrics and types of capacitors based on it.
CO-5:	Applications of electric and electronic materials.

	Syllabus Details
Unit I	Band Theory of Solids, Semiconductors, Electron Effective Mass, Density of States in an Energy Band, Fermi-Dirac Statistics
Unit II	Intrinsic Semiconductors, Extrinsic Semiconductors, Temperature Dependence of Conductivity, Recombination and Minority Carriers, Continuity Equations, Optical Absorption, Ideal PN Junction and Band Diagram, Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET),
Unit III	Supercapacitors, Types of supercapacitor. Ceramic substrates (Al_2O_3, SiC, BeO, AlN, Glass ceramic etc.), Processing of Thick Film, Thin Film, Multi-layer Packages, Properties of Ceramic Insulators, Ceramic Capacitor
Unit IV	Dielectrics-Barium titanate, Other titanate based dielectrics, Composition with high Pb content, Processing of thick and thin film capacitors, Integrated capacitors
Unit V	Relaxor Dielectrics, Piezoelectric Ceramics and electrostrictive materials, Powders and Processes, Piezoelectric ceramic applications. Nano Ceramics: Different Compositions, Synthesis, Applications, Introduction to electric vehicle.

Textbooks

- *Materials for Electronics: R.C. Buchanon.*
- *Introduction to Ceramics: W.D. Kingery*
- *Fundamentals of Ceramics: Barsoum*

Reference Book(s):

- *Physical Ceramics for Engineers: VanVlack*
- *Handbook of Ceramics: Editor S. Kumar Ceramic*
- *Electronic Ceramics: B.C.H Steele.*
- *Adv. Ceram. Materl. Vol I by K Furuta & K U chino*

<u>Course Name: Magnetism and Magnetic Materials</u>
<u>Course Code: MM 615</u>

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*

<u>Course Name: Heat-treatment of Metals and Alloys</u>
<u>Course Code: MM 616</u>

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
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*

M.Sc. Food Technology
(In association with DFRL, Mysore)

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	ACFT 505	Food Analysis & Sensory Evaluation	3	1	4
Semester II					
1	ACFT 506	Technology of Fermented Foods	3	1	4
2	ACFT 507	Food Standards and Safety Management	3	1	4
3	ACFT 508	Technology of Milk & Dairy Products	3	1	4
4	ACFT 509	Fundamentals of Food Engineering	3	1	4
5	Elective I		3	1	4
Semester III					
1	ACFT 510	Technology of Fruits, Vegetables and Plantation Crops	3	1	4
2	ACFT 511	Technology of Cereals, Pulses and Oil Seeds	3	1	4
3	ACFT 512	Technology of Meat, Poultry & Fish Processing	3	1	4
4	ACFT 513	Food Packaging Technology	3	1	4
5	Elective II		3	1	4
Semester IV					
1	ACFT 541	Project work			25
		Total Credits			85

(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	AC-607	Nano chemical Technology
2	AC-610	Recent Advances in Chemistry
3	DRC-601	Research Methodology
4		Online courses from NPTEL, MOOC
5		Open elective from other dept

Elective II

1	AC-605	Advanced Analytical Techniques
2	AC-604	Chemical Process Design
3	ACFT 515	Advanced Food Technology
4	MS-601	Introduction to Materials
5		Online courses from NPTEL, MOOC

DETAILED SYLLABUS

FOOD CHEMISTRY (ACFT 501)

Unit-1. General Introduction & scope: Fundamentals of Chemistry, Physico-chemical and functional properties of various food constituents and importance

Unit-2. Water: Physical properties of Water and Ice, 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. 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. Fatty acids- saturated, mono unsaturated and poly-unsaturated. Chemistry of fats and oil and their role.Modifications of lipids.

Unit-6. Enzymes as biocatalysts – Classifications, chemistry, classification, mode of action, specificity, assay techniques, isolation and purification, stabilization, enzyme kinetics. Applications of enzymes.

Unit-7. Vitamins and Minerals: Classifications, chemistry, structure, biological importance and functions, Role of vitamins in food industry, fortification of foods.

Unit-8. Anti-nutritional factors & natural toxins: Types, Chemistry, structure and physico-chemical properties of anti-nutritional factors & natural toxins present in foods.

Practical

1. Principles and working of common instruments.
2. Analysis of water with respect to pH, TS, TSS, hardness, chlorine, etc.
3. Estimation of moisture, ash and fats
4. Estimation of proteins by various methods,
5. Estimation of sugars, starch and other polysaccharides
6. Estimation of crude and dietary fibres
7. Estimation of minerals and vitamins
8. Determination of minerals-calcium, phosphorus, iron and vitamins
9. Analysis of lipids-saponification value, acid value and iodine value.

References

1. Fennema, O.R.2007. Food Chemistry. Marcel Dekker, CRC Press, New York.
2. Meyer, L.H. 2002. Food Chemistry. CBS publishers and Distributors, New Delhi.
3. Potter, N.N. and Hotchkiss, J.H. (2006), Food Sciences, Fifth edition, CBS publishers and Distributors, New Delhi.
4. Belitz, H.D., Grosch, Werner, Schieberle, Peter 2009. Food Chemistry. Springer Verlag.
5. 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.
6. Salunkhe, D.K. Chavan, J.K., Adsule, R.N. Kadam, S.S. 1992. World Oilseeds: Chemistry, Technology and Utilization, Van Nostrand Reinhold, New York.

FOOD MICROBIOLOGY (ACFT-502)

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 controlfor 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.
2. **Staining techniques**–Monochrome staining, negative staining, gram staining, acid fast staining, spore staining, capsule staining and motility of bacteria.
3. **Pure culture techniques:**Different methods for isolation of pure cultures from spoiled food:
4. **Growth characteristics**:Methods for determination of microbial numbers– direct and plate count; Generation time; various factors influencing microbial growth.
5. **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.
6. **Pathogenic microorganisms**: Different methods for isolation of pathogenic bacteria and fungi from contaminated foods.

References
1. James M.J. (2000) Modern Food Microbiology, 5th Edition, CBS Publishers.
2. Barnart, G.J. (1997) Basic Food Microbiology, CBS Publishers.
3. Adam M.R. & Moss, M.O. (1995) Food Microbiology, New Age International P. ltd.
4. Bibek Ray (1996) Fundamental Food Microbiology, CRC Press.
5. Waits MJ. 2001. Industrial Microbiology. Blackwell Science.
6. Ward OP. 1989. Fermentation Biotechnology. Prentice Hall.
7. Garbutt J. 1997. Essentials of Food Microbiology. Arnold Heinemann.

FOOD AND NUTRITION (ACFT 503)

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.,

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-3. Introduction to nutraceuticals: definitions, synonymous terms, basis of claims for a compounds as a nutraceutical, regulatory issues for nutraceuticals.

References

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

<u>PRINCIPLES OF FOOD PROCESSING AND PRESERVATION(ACFT 504)</u>

Unit-1. Scope and importance:Introduction to food processing and preservation. National and international perspectives.Historical development of food processing and preservation.

Unit-2. Principles of Food Preservation: Basic principles of food preservation. Drying and Dehydration, Freezing, Ionizing and non-ionizing radiations, Chemical preservation.

Unit-3. Food processing methods: Blanching, pasteurization, sterilization, UHT, aseptic processing, canning. Thermal processing and process time calculations.

Unit-4. Advanced methods of food processing: Advanced thermal and non-thermal processes. Hurdle Technologies.

Natural preservation methods using sugar, high salt and fermentation.

Practical

1: Preparation of intermediate moisture & HT foods,

2: Osmotic dehydration of food

3: Modified and controlled atmosphere packaging,

4: Demonstration of food processing machines.

5: Calculation of *D* and *z* values

References

Fellows, P. and Ellis H. 1990. Food Processing Technology: Principles and Practice, New York.

Potter, N. N. and Hotchkiss, J. H. 1995. Food Science, Springer Science, Fifth Edition

<u>**FOOD ANALYSIS & SENSORY EVALUATION (**ACFT 505)</u>

Unit-1. Food Component Analysis: Proximate composition includes protein, fat, moisture ash etc. Analysis of minerals & vitamins & nutritional component. Use of Analytical Techniques in Food Science; Basics, Principles and Applications of UV – Vis Spectrophotometer, Gas Chromatography(GC), High Pressure Liquid Chromatography (HPLC), Atomic Absorption Spectroscopy (AAS), 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)

References

1. Fennema, O.R.2007. Food Chemistry. Marcel Dekker, CRC Press, New York.

2. Ranganna. Analysis of food and vegetables, ICAR, New Delhi.

3. Sensory Evaluation of Food: Principles and Practices; Harry T. Lawless, Hildegarde Heymann, Springer US, 11-Dec-2013.

SEMESTER- II

TECHNOLOGY OF FERMENTED FOODS (ACFT 506)

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.Downstreamprocess. 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

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.

References

1. Prescott & Dunn (1992). Industrial Microbiology, 4th Edition. CBS Publishers, NewDelhi.

2. Ward, O.P. (1989). Fermentation Biotechnology- Principles, Process and Products. Prentice Hall Publishers, New Jersey.

3. Stansbury, P.F., Whitakar, A and Hall, S.J. (1995). Principles of Fermentation Technology, Pergamen Press, Oxford.

4. Rehm, H.J., Read, G.B., Puhler, A and Stadler (1999). Biotechnology, Vol. 1-8, VCH Publications.

5. Crueger and Crueger (2000) Biotechnology – A Text book of Industrial Microbiology. IInd edition. Panima Publishing company
6. Bains W. 1993. *Biotechnology from A to Z*. Oxford Univ. Press.
7. Crueger W &Crueger A. 2000. *Biotechnology: A Textbook of Industrial Microbiology*. Madison, USA.
8. Joshi VK & Pandey A. 2003. *Biotechnology Food Fermentation*. Vols. I, II.Education Publ.
9. Knorr D. 2002. *Food Biotechnology*. Marcel Dekker.

FOOD STANDARDS AND SAFETY MANAGEMENT (ACFT 507)

Unit-1. Importance and functions of 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 such as FSSAI, USFDA, BIS, AGMARK.Quality management systems in India; Food Safety and Standards Act, 2006; Domestic regulations; various organizations (both global and domestic) dealing with inspection, traceability and authentication, certification and quality assurance.

Sampling procedures and plans, specification of raw materials and finished products, Labeling issues; regulations for waste disposals; Concept of Codex Almentarious/USFDA. Quality assurance, Total Quality Management; GMP/GHP; GLP, GAP; Sanitary and hygienic practices; Quality manuals, documentation and audits, Indian & International quality systems and standards like ISO Overview of ISO, structure, interpretation and case studies of food safety and Quality management.

History, structure, principles, HACCP applications, HACCP based SOPs. Export import policy,; Laboratory quality procedures and assessment of laboratory performance; Applications in different food industries; Food adulteration and food safety.

CASE STUDIES

References

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 practicalapproach,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

TECHNOLOGY OF MILK AND MILKPRODUCTS (ACFT 508)

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 dairyequipments. 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* etc.;
11. Determination of adulterants in milk by milk testing kit.

References

1. Aneja RP, Mathur BN, Chandan RC & Banerjee AK. 2002. *Technology of Indian Milk Products*. Dairy India Publ.
2. Walstra P. (Ed.). 2006. *Dairy Science and Technology*. 2nd Ed. Taylor & Francis.
3. Walstra P. 1999. *Dairy Technology*. Marcel Dekker.
4. Dey S.1994. *Outlines of Dairy Technology*. Oxford Univ. Press, New Delhi.
5. 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.
6. Spreer E. 1998. Milk and Dairy Product Technology. Marcel Dekker, New York.

FUNDAMENTALS OF FOOD ENGINEERING (ACFT-509)

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

Recommended Books

1. R.P. Singh and D.R. Heldman, 'Introduction to Food Engineering', Academic Press, INC, London.
2. R.L. Earle, 'Unit Operations in Food Processing', Pergamon Press Oxford, U.K.
3. R.T. Toledo, 'Fundamentals of Food Process Engineering', CBS Publishers, New Delhi, India.
4. J.C. Batty and S.L. Folkman, 'Food Engineering Fundamentals', John Wiley and Sons, New York, U.S.A.
5. J.C. Harper, 'Elements of Food Engineering', AVI, Westport, U.S.A.
6. J.G. Brennan, J.R. Butters, N.D. Cowell and A.E.V. Liley, 'Food Engineering Operations', Elsevier, New York, U.S.A.
7. Harper, J.C. (1976) Elements of Food Engg., AVI Publ. Co., Westport, Connecticut.
8. Brennan, J.Buffers, J.R., Cowell N.D., Lilly, A.E.V. (1976). Food Engg. Operations, 2nd Ed., Elsevier, New York.

9. Lewis, M.J. (1987). Physical Properties of Foods & Foods Processing Systems, Ellis Horwood, England.
10. Fellows, P.J. (2015). Food processing technology. Elsevier India.
11. Berk, Zeri. (2009). Food process engineering and technology. Elsevier India.
12. Smith, P.G. 'Introduction to Food Process Engineering' Springer, 2005.
13. Gopala Rao, Chandra, 'Essential of Food Process Engineering', BS Publications.

SEMESTER – III

TECHNOLOGY OF FRUITS, VEGETABLES & PLANTATION CROPS (ACFT 510)

Unit-1. Introduction to fruits & vegetables: History, scope and importance of fruits and vegetables processing and preservation, National and international perspectives.Post harvest technologies of fruits and vegetables.Factors affecting fruits and vegetables preservation (intrinsic and extrinsic factors).Nature and types of spoilage in fruits and vegetables.

Unit-2. Post harvest Handling & Storage of Fresh Fruits & Vegetables: Chemical composition; pre and postharvest changes, desirable characteristics of fruits and vegetables for processing.Ripening of climacteric and non climacteric fruits, Maturity indices and standards for selected fruits and vegetables, method of maturity determination, Principles of storage, Types of storage: natural, ventilated low temperature storage, CA and MA storages. Hypobaric storage, pre-cooling and cold storage, Zero energy cool chamber, Physiological disorders: chilling injury and diseases, Factor affecting post harvest losses

Unit-3. Fruits & vegetables processing: Role of enzymes in fruits and vegetable processing,Browning in fruits and vegetables, Theory of gel formation, pectin and related compounds,andproductsFermented and non-fermented beverages, Fruit and vegetable, beveragesand fruit based formulations, commodity specific products.

Scope, principle, history, mechanism, advantages and disadvantages of drying and dehydration, methods of dehydration of commercial products, selection of methods based on characteristics of foods to be produced, advantages and disadvantages of different methods. Physical and chemical changes during drying ,control of chemical changes, desirable and undesirable changes. Packaging and storage of dehydrated products.

Unit-4. Plantation crops: Importance of plantation crops, chemical composition and processing of tea, coffee, Cocoa and their quality assessment. Instant coffee and tea, monsoon coffee, cocoa beverage.Cocoa processing and chocolate.Spices and volatiles. Minor spices and spice production, processing of spices.

Practical:

1. Equipment for fruits and vegetable processing & plant-layout,
2. Preparation of fruit juices, squashes, syrups and ready-to-serve beverages.
3. Canning: of fruits and vegetables.
4. Preparation of jams, jellies, marmalade, preserves, and candies.
5. Preparation of pickles, chutneys.
6.Tomato products
7. Drying of fruits and vegetables,
8. Estimation of caffeine in tea and coffee roasting.
9.Grinding,extraction, blending &packaging of coffee, Pectin determination.
10. Estimation of Browning enzymes,PPO& POD.
12. Determination of salt content.

References

1. Dauthy, M.E. 1997. Fruit and Vegetable Processing. International Book Distributing Co. Lucknow, India.
2. Kadar, A. A. 1992. Postharvest Technology of Horticultural Crops. 2nd Ed. University of California.
3. Seymour, G.B., Taylor, J.E. and Tucker, G.A. Ed. 1993. Biochemistry of Fruit Ripening. Chapman and Hall, London.
4. Srivastava, R.P. and Kumar, S. 1998. Fruit and Vegetable Preservation: Principles and Practices. 2nd Ed. International Book Distributing Co. Lucknow.
5. Wildey, R.C. Ed. 1994. Minimally Processed Refrigerated Fruits and Vegetables. Chapman and Hall, London.
6. Wills, R.B.H., McGlasson, W.B., graham, D., Lee, T.H. and Hall, E.G. 1989. Postharvest: An Introduction to the Physiology and Handling of Fruits and Vegetables. BSP Professional Books, Oxford.

TECHNOLOGY OF CEREALS, PULSES AND OIL SEEDS(ACFT 511)

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.

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.

Unit-4. Millets: Structure, Bajra, Jowar and Ragi etc.

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.

Unit-6. Legumes and oilseeds: composition, anti-nutritional factors, processing and storage; processing for production of edible oil, meal, flour, protein concentrates and isolates; extrusion cooking technology; snack foods; development of low cost protein foods.

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

Reference

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. Hoseney RS. 1994. *Principles of Cereal Science and Technology*. 2nd Ed. AACC.
4. Kulp K & Ponte GJ. 2000. *Handbook of Cereal Science and Technology*. 2nd Ed. Marcel Dekker.
5. Lorenz KL.1991. *Handbook of Cereal Science and Technology*. Marcel Dekker.
6. Marshall WE & Wadsworth JI. 1994. *Rice Science and Technology*. Marcel Dekker.
7. Mathews RH. 1989. *Legumes Chemistry, Technology and Human Nutrition*. Marcel Dekker.
8. Salunkhe DK.1992. *World Oilseeds: Chemistry, Technology and Utilization*. VNR.
9. Dubey SC. 2002. *Basic Baking*. The Society of Indian Bakers, New Delhi.
10. Francis FJ. 2000. *Wiley Encyclopedia of Food Science & Technology*. John Wiley & Sons.
11. Manley D. 2000. *Technology of Biscuits, Crackers & Cookies*. 2nd Ed. CRC Press.
12. Pyler EJ. *Bakery Science & Technology*. 3rd Ed. Vols. I, II. Sosland Publ.
13. Qarooni J. 1996. *Flat Bread Technology*. Chapman & Hall.

TECHNOLOGY OF MEAT, POULTRY AND FISH PROCESSING (ACFT 512)

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 anddesignedmeatproducts.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.

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

References

1. Lawrie, R.A. 2006. Meat Science, 7th Edn. Pergamon Press, Oxford UK.

2. Fidel Toldrá. 2010. Handbook of Meat Processing. Blackwell Publishing, USA.

3. Legarreta IG & Hui Y.H. 2010. Handbook of Poultry Science and Technology, Wiley Publications.

4. Stadelmen, W.J. and Cotterill, O.J., 1995. Egg. Science and Technology. Fourth Edition. by CRC Press.

5. Mead G. 2004. Poultry Meat Processing and Quality, Woodhead Publishing, CRC Press, Boca Raton, New York.

6. Kerry, Kerry &Ledward. 2002. Meat Processing, Woodhead Publishing, CRC Press, Boca Raton, New York.

7. Hui YH. 2001. *Meat Science and Applications*. Marcel Dekker. 32

8. Pearson AM & Gillett TA. 1996. *Processed Meat*. 3rd Ed. Chapman & Hall.

9. Stadelman WJ &Cotterill OJ. 2002. *Egg Science and Technology*. 4th Ed. CBS publications, New Delhi.

10. Bremner H. 2002. Safety and Quality Issues in Fish Processing. Publishing, CRC Press, Boca Raton, New York.

11. Pearson A. M and Dutson T. R. 1995. HACCP in Meat, Poultry, and Fish Processing. Springer Science+Business Media Dordrecht, U.K.

FOOD PACKAGING TECHNOLOGY (ACFT 513)

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. Glass: composition, properties, types of closures, methods of bottle making; Metals: types of cans, tin and aluminium based cans, lacquers; Plastics & polymers used in packaging, their chemical structure and properties.

Unit-2. Testing of packaging materials; Mechanical properties their methods of testing and evaluation; Barrier properties of packaging materials: Theoryof permeability, and its measurement, water vapour transmission rate (WVTR) and its measurement, prediction of shelf life of foods using different packaging materials.

Migration from packaging materials, Physical process, Partition Coefficient and sorption process, Determination of migration, food stimulants, Flavour adsorption and sorption, Packaging flavour interaction.

Unit-3. Different forms of packaging; rigid, semi rigid and flexible, Liquid and powder filling machines; bottling machines, Form fill seal and multilayer aseptic packaging machines, Packaging Systems and methods, Packaging systems for dehydrated foods, frozen foods, Fats and Oils, dairy products, fresh fruits and vegetables, meat, poultry and sea foods.

Role of packaging in food marketing, aesthetic and graphic design of labels; Coding and marking; nutrition labelling, RFID tag, bar coding, Packaging Laws and regulations, safety aspects of packaging materials; Overall and specific migration, Packaging material residues in food products; Environmental& Economic issues, recycling and waste disposal.

Practical

1. Identification and testing of packaging materials, Determination of Grammage, water proofness,
2. Testing of lacquered tin plate sheets;
3. Measurement of tin coating weight; sulphide stain test;
4. Determination of equilibrium moisture content;
5. Grading of glass bottles for alkalinity;
6. Determination of physico – mechanical properties of polymer packaging materials,
7. Determination of water vapour and gas transmission rate of packaging material.
8. Determination of gas composition by Head space analyser.

References

1. Robertson, G.L. 2006 Food Packaging: Principles and Practice (2nd ed.), Taylor & Francis.

2. Kadoya T. (Ed). 1990. Food Packaging, Academic Press INC.

3. Mahadeviah M &Gowramma RV. 1996. Food Packaging Materials, Tata McGraw Hill.

4. Gowariker, V.R., Viswanatahan, N. V, Sreedhar, J. 1986, Polymer Science, New Age International (P) Ltd, New Delhi.

5. Ahvenainen, R. (Ed.) 2003, Novel Food Packaging Techniques, CRC Press.

6. Han, J.H. (Ed.) 2005, Innovations in Food Packaging, Elsevier Academic Press.

7. Yam, K. L, Lee, D. S. (Ed.), 2012, Emerging Food Packaging Technologies: Principles and Practice, Woodhead Publishing Ltd.

ELECTIVE – I

AC-607: NANO-CHEMICAL TECHNOLOGY

Unit-1. Introduction: Definition and concept- dimensionality and size dependent phenomena. 9 Nano and Mesopores materials: Chemistry of size dependent variation in nanomaterials, reactivity etc. Nano-fluids: Basic chemistry of nano-fluids, preparation of nano-fluids, analysis of nano-fluids, applications of nano-fluids. Nanostructures: Chemistry of Quantum dots, nanowires and nanotubes, 2D films. Nano-energetic materials: Introduction, nano-thermites, Advantages and examples, synthesis and thermal properties of nano-thermites. Nano-catalysts: Surface chemistry of nanoparticles, examples, photo-catalysis Polymer nano-composites and hybrid materials: Preparation, Characterization, Applications Nanotechnology for chemical industry: Application in pharmaceuticals, Paint, Coatings, rubber and polymers. Other Topics: Application of nanochemistry/ nanomaterials in civil and defence sector, Characterization of nanoparticles by various analytical techniques

Unit-2. TRAINING AND PRACTICALS: Synthesis of metal nanoparticles¬& analysis by particle size distribution and UV-Visible spectroscopy Synthesis of quantum dots and analysis by UV-Visible spectroscopy and Photoluminescence¬ spectroscopy

TEXT/REFERENCES:-

1. Nanochemistry: K. Klabunde and Gleb B. Sergeev, Elsevier (2013)
2. Nanotechnology: basic science and emerging technologies – Mick Wilson, KamaliKannangara, Geoff Smith, Michelle Simmons, BurkhardRaguse, Overseas Press(2005).
3. Nanocomposite science and technology, Pulickel M. Ajayan, Linda S. Schadler, Paul V. Braun, Wiley-VCH Verlag, Weihem(2003).
4. Nanotechnology – Edited by Gregory Timp, 1999, Springer
5. Nanocrystal Quantum Dots - Edited by Victor I. Klimov, Second Edition, CRC Press

<u>RECENT ADVANCES IN CHEMISTRY (AC-610)</u>

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 smartmaterials: Smart materials, their properties, distribution by type chemistry of macromolecules, phase change materials

TEXT/REFERENCES:

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. Essentials of Pharmaceutical Chemistry, D. Cairns
5. Intelligent Materials, M. Shahinpoor, H.-J. Schneider, RSC, 2008.

<u>Research Methodology (DRC-601)</u>

Introduction, statement of problem, Searching the literature, choice of problem scientific methods in research, E-resources, databases, Execution, analysis and interpretation, Experimental work, design, measurements, Review of published research in the relevant field, plagiarism, Computer Applications, Software tools, simulation tools, Basic statistics and probability distributions, Hypothesis testing, Simulation techniques, Mathematical Modeling, Quantitative Analysis, Technical writing, Report, thesis, Research ethics, Paper Writing, Paper Writing

ELECTIVE – II

ADVANCED ANALYTICAL TECHNIQUES (AC-605)

Unit-1. Instrumental Analysis: Qualitative analysis, genesis of instrumental analysis, hyphenated techniques Polymeric Techniques: Rheology Techniques, Molecular weight determination

Unit-2. Thermal Techniques: ThermoGravimetry (TG), Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC)

Unit-3. Chromatographic Techniques: Gas Chromatography (GC), High Performance Liquid Chromatography (HPLC), Thin Layer Chromatography (TLC), Ion chromatography. Spectroscopy: Ultra Violet-Visible Spectroscopy UV-VIS, Infra-Red spectroscopy (IR), Nuclear Magnetic Resonance (NMR), Mass spectroscopy, Atomic Absorption Spectroscopy (AAS) Analytical techniques for defence: Types and Implementations. TRAINING AND PRACTICALS: Handling and demonstration of FTIR, UV-visible spectrophotometer, Mass spectrometer, LCMS, HPLC and GC. Analysis of organic compounds by IR and UV-Visible spectroscopy.

TEXT / REFERENCES:-

1. Analytical chemistry, 4th edition, G. D. Christian, John Wiley & Sons, New York, (1986).
2. Introduction to Spectroscopy, 4th Edition, D. Pavia, G. Lampman, G. Kriz, J. Vyvyan, Brooks/Crole, 2009.
3. Chromatographic Methods, 5th Edition, A. Braithwaite and F. J. Smith, Chapman and Hall, London (1985).
4. Spectroscopic Identification of Organic Compounds by R. M. Silverstein and G. C. Bassler, 4th edition, Morrill Tevence (1981)
5. Analytical chemistry by G. C. Christian, John Wiley & Sons (1980) Analysis of Explosives by Yitrin&Yinon, Pergamon Press, 1981

Chemical Process Design (AC-604)

1. A strategy for process synthesis and analysis: The nature of process synthesis and analysis; Engineering Economics; Economic decision making.
2. Cost diagrams and quick screening of process alternatives.
3. Recycle structure of the flow-sheet
4. Separation system;
5. Heat Exchanger networks; Process development for energy harvesting
6. Developing a conceptual design and finding the best flow-sheet: Input information and batch vs. continuous; Input output structure of the flow sheet
7. Computational methods in process design

TEXT/REFERENCES:-

1. *Conceptual Design of Chemical Processes*, J. M. Douglas, McGraw Hill, 1988.
2. *Chemical Process Design*, A. C. Dimian, C. S. Bidea, Wiley-VCH, 2008.
3. Computational Methods in Process Simulation, By W. Fred Ramirez, Antony Rowe Ltd. (1997)

ADVANCED FOOD TECHNOLOGY (ACFT 515)

Unit-1. Introduction, Scope and importance of advanced techniques in food technology, Importance and types of thermal and non thermal processing techniques.

Dielectric heating, Microwave heating, Ohmic heating, Infrared heating, RF heating, Extrusion cooking (Introduction, processing equipment and design, Mode of action, Biological effect and application in food processing).

High hydrostatic pressure in food processing, High intensity pulsed electric field processing, High pressure CO2 processing, Ozone (O3) processing, Electron beam processing, Pulsed light processing, Ultrasonication, Combination processing, Plasma processing, (Introduction, processing equipment and design, Mode of action, Biological effect and application in food processing).

Unit-2. Application of nanotechnology in food systems, Introduction and applications in foods human nutrition, preservation, processing. Packaging

References

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.

<u>INTRODUCTION TO MATERIALS (MS 601)</u>

Unit-1. Introduction, classification of materials; atomic structure, bonding in solids, bonding forces and energies; crystal structure, unit cells, crystal systems, crystallographic points, directions, and planes, crystalline and non-crystalline materials, anisotropy; Structure of crystalline solids: metallic crystal structure, ceramic crystal structure, polymer crystal structure, determination of crystal structure; imperfection in solids: point defects, linear defects, interfacial defects, bulk or volume defects, defects in polymer; phase diagrams: definition and basic concept, phase equilibria, one-component phase diagram, Binary phase diagrams.

Text/Reference:

Materials Science and Engineering by William D. Callister, JohnWiley& Sons, Inc. Elements of Materials Science and Engineering by Lawrence H. van Vlack.

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 in Defence University, the Department offers M. Tech and Ph. D. programs on materials engineering and engaged in conducting various short term courses to 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 the defence need further, department would like to offer M.Sc. program in Materials Science for B.Sc. graduates.

This programme is offered for DRDO employs and Officers from Tri-services, Defence public sector undertaking, ISRO/DAE personal, industry personal, faculties from institutes/universities and for civilian students. This program is also open to friendly foreign countries.

At present, the Department is equipped with major characterization facilities 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, super critical foaming technology 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. 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 Post-graduate School (NPS), California, Crainfield University, UK, Loughborough University, UK, National Ding Hwa University, Taiwan, Weizmann Institute of Science, Israel etc.

Eligibility:

The eligibility for the M.Sc. postgraduate programme is B.Sc. or equivalent in any branch of science/mathematics or BE/B.Tech in any branch of Engineering.

Organization:

The programme is of four-semester duration. In first, second and third semester have 5 courses respectively. The program is having one seminar in the second semester. Third semester also includes project phase 1 along with 5 courses. Last (fourth) semester will have second phase of the project (Project phase II). In the first, second and third semester the students have options 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. As part of the dissertation work in the third semester, the dissertation work will be evaluated by the expert committee at the end of the third semester. At the end of the final (fourth) semester, students will submit their thesis before going for final evaluation and present their project works before the expert committee (consists of External / Internal members from various R&D organisations / 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	Introduction to Materials Science	3	2	4
2	MS 502	Material Characterization Techniques	3	2	4
3	MS 503	Materials Thermodynamics and Kinetics	3	1	4
4	MS 504	Polymeric Materials	3	2	4
5	MS 505	Introduction to Computational Materials Science	3	1	4

Total credit --20

Semester II

Sr. No.	**Course Code**	**Subjects (Theory/Practical)**	**Contact Hours**		**Credits**
			L	**T/P**	
1	MS506	Processing of Metals, Ceramics and Polymers	3	2	4
2	MS 507	Introduction to Metallurgy	3	1	4
3	MS 508	Non-destructive Testing	3	2	4
4	MS 509	Biomaterials	3	1	4
5	MS 510	Composite Materials	3	1	4

Total credit --20

Semester III

Sr. No.	**Course Code**	**Subjects (Theory/Practical)**	**Contact Hours**		**Credits**
			L	**T/P**	
1	MS 511	Nanoscience and Nanotechnology	3	1	4
2	MS 512	Additive Manufacturing of Materials	3	1	4
3	MS 513	Polymer Blends and Nanocomposites	3	1	4
4		Elective I	3	1/2	4
5		Elective II	3	1/2	4

Total credit -- 20

Semester IV

Sr. No.	**Course Code**	**Subjects (Theory/Practical)**	**Contact Hours**		**Credits**
			L	**T/P**	
1	MS 541	Dissertation			25

Total credit – 25

List of Electives

Sr. No.	**Course Code**	**Name of the Course**
Electives from the Department		
1	MS 514	Advanced Functional Materials
2	MM 617	Materials for High Temperature Applications
3	MM 614	Electrical and Electronic Materials
4	MM 616	Heat-treatment of Metals and Alloys
5	MM 610	Nanomaterial and Their Applications
Open Electives from other Departments		
6	ME 602	Advanced Mechanics of Materials
7	ME 603	Advanced Fluid and Thermal Science
8	ME 604	Advanced Materials and Processing
9	AP 614	Sensors and Actuators
10	AP 601	Principles of sensing: Material Science and Physics

Course Name: Introduction to Materials Science
Course Code: MS501

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 equllibria in ceramic crystals
Unit IV: Dielectrics:Dielectric strength, Loss factor. Equivalent circuit description of linear dielectrics, Power factor, Dielectric polarisation, Polarisation mechanisms,
Unit V: Practical: 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 Name: Material Characterization Techniques
Course code: MS 502

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, 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 EDS applications, X-ray Photon Spectroscopy and Auger electron spectroscopy
Unit IV
Thermal Analysis Techniques- DSC, DTA and TGA
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

C**ourse Name: Materials Thermodynamics and Kinetics**
Course code: MS 503

Unit I: Simple and composite systems, phases, Internal energy, Enthalpy, Entropy, Gibbs Free energy, Specific heat, Laws of thermodynamics, Reversible and Irreversible processes.
Unit II: Generation of Auxiliary Functions: Legendre transforms, Coefficient relations, Maxwells relations, Thermodynamic relations among state functions variables and its application to solids.
Unit III: Free energy of single component system: Free energy as a function of temperature, Clausius-Clapeyron Equation, Driving force for solidification.
Unit IV: 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 V: Diffusion: Phenomenology, First and Second law of diffusion, Solution to diffusion equations and error function, Types of diffusion

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 Name: Polymeric Materials
Course Code: MS 504

- Introduction: Background, Nomenclature, Classifications, Molecular Weight, Examples of Applications, Principles of Polymerization
- Synthesis of Polymers: Step-Growth Polymerization, Radical Chain Polymerization
- Synthesis of Polymers: Radical Chain Polymerization (cont.), Controlled Radical Polymerization, Emulsion Polymerization.
- Synthesis of Polymers: Ionic Chain Polymerization, Coordination Polymerization, Ring-Opening Polymerization, Copolymerization
- Characterization of Polymers: Polymers in Solution, Chain Dimension, Determination of Molecular Weight
- Determination of Molecular Weight (cont.), Frictional Properties of Polymers in Solution, Hydrodynamic Size, Chemical Composition, Polymer Processing
- Phase Structure and Morphology of Bulk Polymers: Amorphous and Crystalline States, Viscoelasticity, Multicomponent Polymer Systems, Properties of Bulk Polymers.
- Properties of Bulk Polymers : Mechanical, Optical, Electrical, Surface and Other Industrially Relevant Properties, Polymer Degradation and Stability, Polymer Additives, Few Contemporary Topics, Challenges and Opportunities in Polymer Science.

Text Book(s):

- V.R. Gowariker, Polymer Science, Wiley Eastern, 1995
- F. N. Billmeyer, Textbook of Polymer Science, Wiley Interscience, 1971.

Reference Books:

- 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: Introduction to computational materials Science
Course Code: MS 505

Unit I: Introduction to modelling and simulation; Predator-Prey model; Review of programming concepts in high level languages such as Matlab and low level languages such as C / C++
Unit II: Scales in materials structure and behaviour; Data-fitting and data-driven modeling; Quantification of experimental microstructures using MATLAB
Unit III: Numerical methods; Numerical integration; Numerical solution of diffusion equation
Unit IV: Mesoscopic modelling: Monte Carlo method; Diffuse-interface modelling and their application in Materials Science
Unit V: Evaluation of properties from the computed microstructures using mean field and full field approaches; Principal component analysis and its application

Text Book(s):

- 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: Processing of Metals, Ceramics and Polymers
Course Code: MS 506

Unit 1: Processing of Polymers- Extrusion, compounding, fibre spinning, injection moulding, compression moulding
Unit 2: Processing of ceramics- Compaction, moulding, sintering, refractory manufacturing processes
Unit 3: Processing of Metals- Casting, Hot working, Cold working, Rolling, Annealing, Forging, Extrusion,
Unit 4: Wire drawing, Sheet metal forming, Joining Techniques, Friction stir welding, Powder Metallurgy
Unit 5: Practical: Metal processing- rolling, annealing; polymer processing-Extrusion and compression molding, electrospinning

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. Powder 436

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: Introduction to Metallurgy
Course Code: MS 507

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
Text/Reference Books:
1. Introduction to Physical Metallurgy, S H Avner, TATA Mc-Graw Hill, New Delhi, 2001.
2. Morden Physical Metallurgy, 8th Ed, R.E. Smallman, A.H.W. NGAN, Butterworth Heinemann publications, 2014 417
3. Mechanical Metallurgy, 3rd Ed, George E Dieter, Mc-Graw Hill, New York, 1986
4. Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors

Course Name: Non-Destructive Testing
Course Code: MS 508

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.

Test Book(s)
1. Non-destructive Testing of welds, Baldev Raj, C.V. Subramanian and T. Jayakumar, Narosa Publishing House, 2000, Delhi.
Reference book(s)

2. International Advances in non-destructive testing, (Ed.) W. J. Mcgonnagle, Gordon and Breach Science Publishers, 1981, NY.
3. Non-destructive Testing, Views, Reviews, Previews, (Ed.) L.L.Alston, Oxford University Press, 1970
4. Nondestructive Evaluation and quality control, ASM handbook, Volume 17,ASM International

Course Name: Biomaterials
Course Code: MS 509

Unit I: Introduction to biomaterials, Tissue Engineering, Biocompatibility, Biodegradation Biofluids and medical devices, Biostructures
Unit II: Ceramic based biomaterials, metallic biomaterials, polymer based biomaterials, Biofluidici, 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: Lotusleaf, Gecko feet, Nacre/Bone. Application of nanocomposite biomaterials: artificial biomaterials, antidragcoatings,self-cleaning surfaces,sensors, Riboswitches

Text Book(s):
- Biomaterials- An Introduction, Joon Park- Publisher Springer 423

Reference Book(s):
- Biomaterials- Principals and Applications- Joon Park- CRC Press
- Handbook of Biomaterial Properties- Garth Hastings- Springer
- Handbook of Biomaterials Properties- William Murphy- Springer
- Handbook of Biomaterial Properties- Jonathan Black- Chapman and Hal

Course Name: Composite Materials
Course Code: MS 510

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 fibres – rovings -woven fabrics – non woven random mats – various types of fibres. PMC processes – hand lay up processes – spray up processes – compression moulding – reinforced reaction injection moulding – resin transfer moulding – Pultrusion – Filament winding – Injection moulding. Fibre reinforced plastics (FRP), Glass Fibre Reinforced Plastics (GFRP). Laminates- Balanced Laminates, Symmetric Laminates, Angle Ply Laminates, Cross Ply Laminates.-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 – fibres. 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
Mechanics of Composites, basic constitutive equations, rule of mixture, Halpin-Tsai equations etc.

Text Books:
1. Mathews F. L. and Rawlings R. D., Composite Materials: Engineering and Science, 1st Edition, Chapman and Hall, London, England, 1994.
2. Chawla K. K., Composite materials, Second Edition, Springer – Verlag, 1998.
3. Introduction to Materials Engineering, William Callister

References:
1. Clyne, T. W. and Withers, P. J., Introduction to Metal Matrix Composites, Cambridge University Press, 1993.
2. Strong, A.B., Fundamentals of Composite Manufacturing, SME, 1989.
3. Sharma, S.C., Composite materials, Narosa Publications, 2000.
4. Broutman, L.J. and Krock,R.M., Modern Composite Materials, Addison-Wesley, 1967.
5. ASM Hand Book, Composites, Vol.21, ASM International, 2001.

Course Name: Nanoscience and Nanotechnology
Course Code: MS 511

Unit 1: Overview of Nanostructures and Nanomaterials; Synthesis of Nanomaterials: Types and strategies for synthesis of nanomaterials;
Unit 2: 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 3: Cells response to Nanostructures; Surfaces and interfaces in nanostructures, Ceramic interfaces, Superhydrophobic surfaces, Grain boundaries in Nanocrystalline materials,

Unit 4: Thermodynamics of Nanomaterials; Overview of properties of nanostructures and nanomaterials; Overview of characterization of nanostructures and nanomaterials

Unit 5: Applications of Nanotechnology in various fields

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: Polymer Blends and Nanocomposites
Course Code: MS 512

Unit I
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 property of blends and nanocomposites. 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 and other nanoparticles and their polymer nanocomposites. Surface treatment of the reinforcing materials and interface/interphase structures of composites/nanocomposites. The concept of nanoparticle percolation.

Unit IV

Various processing techniques like solution mixing, melt processing, electrospinning. Physical and thermo-mechanical properties of polymer blends, composites and nanocomposites, Potential applications in Defence.

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 Josheph H. Koo (McGraw-Hill Nanoscience and Technology)

Course Name: Additive Manufacturing of Materials

Course Code: MS 513

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

Test Books:

1. Chua C.K., Leong K.F., and Lim C.C., "Rapid prototyping: Principles and applications". Third Edition, World Scientific Publishers, 2010.
2. Gebhardt A., "Rapid prototyping", Hanser Gardener Publications, 2003.

Reference Books:

1. Liou L.W. and Liou F.W., "Rapid Prototyping and Engineering applications: A tool box prototype development", CRC Press, 2007.
2. Kamrani A.K. and Nase E.A., "Rapid Prototyping: Theory and practice: Springer, 2006.
3. Hilton P.D. and Jacobs P.F., "Rapid Tooling: Technologies and Industrial Applications", CRC press, 2000.
4. Dougles Bryden, "CAD and Prototyping for Product Design", 2014

Course Name: Advanced Functional Materials
Course Code: MS 514

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

Text/References
Shape memory Materials: K. Otsuka and C. M. Wayman; Cambridge University Press
Principles of Electronic Materials and Devices: S. O. Kasap; McGraw Hill Publications

Course Name: Materials for High-Temperature Applications
Course Code: MM 617

Unit 1: Melt processing of Superalloy, Single crystal Superalloy, Processing of superalloy, Alloying effect.
Unit 2: Oxide Dispersion Strengthened alloys. Powder Metallurgy
Unit 3: High temperature deformation, Room and high temperature Wear, Advanced coating materials
Unit 4: Fiber Reinforced Composite Superalloy,
Unit 5: Processing and properties of advanced Structural Ceramics.

Text Book(s):
- 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