DEPARTMENT OF MECHANICAL ENGINEERING

Scheme of Instruction
and
Syllabus of

B.E. (Mechanical Engineering)
V & VI SEMESTER

***With effected from the Academic Year* 2024-2025**

UNIVERSITY COLLEGE OF ENGINEERING
(AUTONOMOUS)
OSMANIA UNIVERSITY
HYDERABAD–500007, TELANGANA.

UNIVERSITY COLLEGE OF ENGINEERING (AUTONOMOUS)

Vision

The Vision of the Institute is to generate and disseminate knowledge through a harmonious blending of Science, Engineering and Technology. To serve the society by developing a modern technology in students' heightened intellectual, cultural, ethical and humane sensitivities, fostering a scientific temper and promoting professional and technological expertise.

Mission

- To achieve excellence in Teaching and Research.
- To generate, disseminate and preserve knowledge.
- To enable empowerment through knowledge and information.
- Advancement of knowledge in Engineering, Science and Technology.
- Promote learning in free thinking and innovative environment.
- Cultivate skills, attitudes to promote knowledge creation.
- Rendering socially relevant technical services for the community.
- To impart new skills of technology development.
- To inculcate entrepreneurial talents and technology appreciation programmes.
- Technology transfer and incubation.

DEPARTMENT OF MECHANICAL ENGINEERING

Vision

To generate and disseminate knowledge in Mechanical Engineering and nurture professional, technical and scientific temper for serving the needs of the industry, research organizations and society.

Mission

- Create technically competent mechanical engineers to suit the changing needs of global industry and society.
- To cultivate skills, attitudes to promote knowledge creation and technology development.
- Interact with prominent educational institutions and R&D organizations for enhancing teaching, research and consultancy services.

Programme Educational Objectives (PEOs) for B.E. (Mechanical Engineering) Programme

PEO 1	To provide the requisite fundamentals of varied subjects related to Mechanical Engineering to conceive, plan, model, design, construct, maintain and improve systems to enhance human comfort.
PEO 2	To provide knowledge of experimental, computational, analytical, simulation tools and techniques require to address the challenges in Mechanical Engineering and other allied fields.
PEO 3	To provide knowledge to apply Mechanical Engineering Fundamentals to design and implement cost effective systems in manufacturing.
PEO 4	To provide effective communication skills, creative methods, ethics and continuous learning techniques to fulfill their professional requirements and societal needs.

Programme Outcomes (POs) of B.E. (Mechanical Engineering) Programme

Engineering Graduates will be able to:

PO1	**Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and a mechanical engineering to the solution of complex engineering problems.
PO2	**Problem Analysis:** Identify, formulate, review research literature, and analyze complex engineering problems related to mechanical engineering and allied fields reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems:** Use research based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the Mechanical engineering practice.
PO7	**Environment and sustainability:** Understand the impact of the Mechanical engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the mechanical engineering practice.
PO9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance:** Demonstrate knowledge and understanding of the mechanical engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Lifelong learning:** Recognize the need for and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Programme Specific Outcomes (PSOs) of B.E. (Mechanical Engineering) Programme

Engineering Graduates will be able to:

PSO1	Apply the principles of collaborative and multi-disciplinary approach for solving problems.
PSO2	Able to interact with industry and R&D institutions leading to start-ups/ budding entrepreneurs.

SCHEME OF INSTRUCTION EXAMINATION
B.E V Semester (Mechanical Engineering)

S.No.	Course Code	Course Title	Scheme of Instruction			Contact hrs/wk	Scheme of Examination		Credits
			L	T	P		CIE	SEE	
1	PC501ME	Dynamics of Machines	3	0	0	3	40	60	3
2	PC502ME	Fluid Mechanics and Hydraulic Machines	3	0	0	3	40	60	3
3	PC503ME	Heat Transfer	3	0	0	3	40	60	3
4	PC504ME	Machine Design	3	0	0	3	40	60	3
5	PC505ME	Metal Cutting and Machine Tools	3	0	0	3	40	60	3
Professional Elective – I									
6	PE511ME	Production Planning and Control	3	0	0	3	40	60	3
	PE512ME	Theory of Elasticity							
	PE513ME	Sustainable Energy Technologies							
	PE514ME	Nanomaterials and Technology							
PRACTICALS									
7	PC 551ME	Fluid Mechanics and Hydraulic Machines Lab	-	-	2	2	25	50	1
8	PC 552ME	Dynamics of Machines Lab	-	-	2	2	25	50	1
Total			**18**	**0**	**4**	**22**	**290**	**480**	**20**

Course Code	Course Title						Course Type
PC501ME	**DYNAMICS OF MACHINES**						**Core**
Prerequisite	Contact hours per week				**Duration of SEE (Hours)**	**Scheme of Evaluation**	**Credits**
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

Course Objectives:

- To find static and dynamic forces on planar mechanisms.
- To know the causes and effects of unbalanced forces in machine members.
- To determine natural frequencies of undamped, damped and forced vibrating systems of one, two and multi degree freedom systems.

Course Outcomes: Upon successful completion of this course, the student will be able to:

1 Compare and contrast various methods of static and dynamic analysis of planar and spatial mechanisms.
2 Evaluate Gyroscopic effects on Naval ships, Aeroplanes and Automobile.
3 Analyze balancing problems in rotating and reciprocating machinery.
4 Design systems like governors and flywheels for controlling speed and energy fluctuations.
5 Determine natural frequencies and conditions for resonance of single degree and multi degree systems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	1	1	-	-	-	-	-	-	1	1	1
CO2	3	2	2	1	1	-	-	-	-	-	-	1	1	1
CO3	3	3	2	1	1	-	-	-	-	-	-	1	1	1
CO4	3	3	3	1	1	-	-	-	-	-	-	1	1	1
CO5	3	2	2	1	1	-	-	-	-	-	-	1	1	1

UNIT-I

Static and Dynamic analysis of planar mechanisms: Graphical and analytical methods, Free body diagrams, Method of superposition, Equivalent offset inertia force, Inertia force in reciprocating engines, Flywheels.

UNIT-II

Force analysis of space mechanisms, inertia matrix, Lagrangian and Newton-Euler formulation. Gyroscopic effect in shafts, aero planes, Naval ships, Two & Four wheel automobiles.

UNIT-III

Balancing of Rotating systems: Unbalanced forces and Couples in rotating systems. Static and dynamic balancing of single plane and multi plane rotating systems. Overview of balancing machines and field balancing.

Balancing of Reciprocating systems: Primary and secondary balancing of single and multi-cylinder inline engines, V-engines and radial engines.

UNIT-IV

Mathematical modeling of single degree of freedom systems. Free and forced vibrations of single degree of freedom systems, case studies on rotating/reciprocating unbalances, whirling of rotors, transmissibility and vibration isolation.
Natural frequencies of two-degree freedom linear systems. Nodes in three rotor systems. Modes of vibration, determining natural frequencies by Holzer's method for multi-rotor systems. Dunkerley's method, Raleigh's method

UNIT-V
The role of a centrifugal governor in speed control, Porter and Hartnell type governors, speed vs lift curves, power and stability.

Suggested Readings:

1. R L Norton, Kinematics and Dynamics of Machinery, McGraw Hill reprint, 2nd Edition, 2016.
2. S.S. Rathan, "Theory of Machines", Tata-Mc Graw Hill, 1995.
3. A. Ghosh and Mallick, "Theory of mechanisms and machines", Affiliated to E-W Press, 1988.
4. John.J.Vicker, Gordon R. Pennock, Joseph E. Shigley, "Theory of Machines & Mechanisms", Oxford University Press, 2003.
5. Venkatachalam, R , Mechanical Vibrations,., PHI, 2014.

Additional Readings:

1. Thomas Bevan, "Theory of Machines", 3rd edition, Pearson Education, 2005.

Course Code	Course Title						Course Type
PC502ME	**FLUID MECHANICS AND HYDRAULIC MACHINES**						**Core**
Prerequisite	Contact hours per week				**Duration of SEE (Hours)**	**Scheme of Evaluation**	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

Course Objectives:

- To understand the properties of fluids and types of fluids.
- To verify the Bernoulli's theorem and its applications.
- To understand the concepts of fluid flow measurement and flow through pipes.
- To introduce the concepts of the working and design aspects of hydraulic machines like turbines and pumps and their applications.
- To determine the basic principles and characteristic curves of turbines and pumps.

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Define the properties of fluids and classify the fluids.
2. Apply conservation laws to fluid flow problems in engineering applications and examine the stability of a floating bodies.
3. Apply Euler's Equation of motion and Bernoulli's equation for flow measuring devices and hydraulic machines.
4. Illustrate the working of Hydraulic machines.
5. Analyze the performance of various types of Hydraulic pumps and turbines.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	1	1	1	-	-	-	-	-	-	1	1	-
CO2	3	3	3	3	1	-	-	-	-	-	-	1	1	-
CO3	3	3	3	3	1	-	-	-	-	-	-	1	1	-
CO4	3	2	2	2	1	-	-	-	-	-	-	2	1	1
CO5	3	3	3	3	1	-	-	-	-	-	-	2	1	1

UNIT-I

Fluid Properties: Viscosity of liquids. Newtonian and non-Newtonian fluids. Surface tension, capillary effect, vapor pressure and cavitation. Ideal and real fluids, Incompressible and Compressible flows. Stream lines, Path lines.

Pressures and pressure head: Types of pressures, Pascal's law of pressure at a point, variation of pressure vertically in a fluid under gravity.

Static Forces on Surface and Buoyancy:

Fluid statics, action of fluid pressure on surface, resultant force and center of pressure on a plane surface under uniform pressure. Equilibrium of floating bodies, stability of a submerged body, stability of floating bodies, determination of the metacentric height, determination of the position of the metacentre relative to the center of buoyancy.

UNIT-II

Laws of fluid flow – Continuity equation. Derivation of Euler's and Bernoull's equations. Application of Bernoulli's equations. Flow measuring devices-Venturimeter, Orificemeter and Pitot static tube. **Viscous Flow:** Reynolds number and Reynolds experiment, flow of viscous fluid through circular pipe-Hagen Poiseuille formula.

Flow through pipes: Head losses in pipes, bends and fittings. Major energy losses, Minor energy losses, Hydraulic gradient and total energy lines, Pipes in series and parallel, Equivalent pipes. Boundary layer theory.

UNIT-III

Reciprocating pumps: Classification, working details, theory and terms used for single and double acting pumps. Effect of acceleration head and friction. Indicator diagrams. Effect of cavitation and limiting suction head on pump speed. Variation of pressure inside pump cylinder during suction and delivery strokes. Work done, power required and efficiency. Functions of air vessels. Work saved and rate of flow from air vessels. Losses and performance curves for reciprocating pumps. Industrial applications. Types of Positive displacement pumps.

UNIT-IV

Centrifugal pumps: Working and constructional details of single stage centrifugal pump. Priming – significance and methods of priming. Basic classification of CF pumps. Types of impellers, casings and vane shapes used. Simple and multistage pumps and their applications. Series and parallel operation of CF pumps. Manometric head and its importance. Manometric efficiency and other efficiencies. Losses in CF pumps. Velocity diagrams. Cavitation. Unit quantities, specific speed. Performance and characteristic curves. Methods of balancing of end thrust in CF pump installations.

UNIT-V

Hydraulic Turbines: Classification of impulse and reaction turbines and their differences in working. Impulse turbines: Salient features and working details of Pelton wheel installation. Velocity diagrams. Calculation of number of buckets, bucket sizes and power developed. Overall efficiency, speed regulation methods.

Reaction turbines: Constructional details and working of Francis and Kaplan turbines. Draft tube in reaction turbines. Theory, types and efficiency of draft tubes. Velocity diagrams. Power developed and efficiencies, pressure head at inlet of the runner.

Principles of similarity applied to hydraulic turbines. Unit quantities, specific speed and its significance for turbine selection. Performance and characteristic curves for Pelton wheel, Francis and Kaplan turbines. Governing of turbines. Cavitation effects in reaction turbines and remedial measures. Surge tanks.

Suggested Reading:

1. Modi, P.N. & Seth, S.M., “Hydraulics & Fluid Mechanics Including Hydraulics Machines”,
   Standard Book House, 2017.
2. K. Subramanya, “Theory and Applications of Fluid Mechanics”, Tata McGraw-Hill Publishing Company Ltd.,1993.
3. S.K.Som, Gautam Biswas, S Chakraborty. “Introduction to Fluid Mechanics and Fluid Machines”, McGraw Hill Education, 2017.
4. K.L. Kumar, “Engineering Fluid Mechanics”, Eurasia Publishing House Pvt Ltd., New Delhi,2009.
5. A.K.Mohanty. “Fluid Mechanics”, PHI Learning Pvt. Ltd, 1994.

Course Code	Course Title						Course Type
PC503ME	**HEAT TRANSFER**						**Core**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To understand the fundamental principles and laws of heat transfer and to explore the implications of these principles for system behaviour.
- To formulate the models necessary to study, analyse and design heat transfer systems through the application of these principles.
- To develop the problem-solving skills essential to good engineering practice of heat transfer in real-world applications.

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Illustrate the basic modes of heat transfer with its associated laws in simple geometries.
2. Solve the problems of steady state and transient heat conduction with simple and multi-layer geometries.
3. Analyze heat transfer coefficients for free and forced convection, considering boundary layers.
4. Develop relationships for radiation exchange between surfaces in an enclosure, blackbody radiation exchange.
5. Analyse heat exchanger performance by using the methods of Log Mean Temperature Difference (LMTD), effectiveness-NTU, and also focus on the knowledge of boiling and condensation.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	1	1	-	-	-	-	-	-	-	2	-	-
CO2	3	2	2	2	-	-	-	-	-	-	-	2	1	2
CO3	3	3	2	2	-	-	-	-	-	-	-	2	1	2
CO4	3	2	1	1	-	-	-	-	-	-	-	2	-	-
CO5	3	3	2	2	-	-	-	-	-	-	-	2	1	2

UNIT-I

Heat transfer fundamentals: Basic heat transfer mechanisms (conduction, convection and radiation), Conduction: General conduction equation on plane wall, Cylinders and spheres. One dimensional steady state conduction through plane walls, hollow cylinders and spheres with and without heat generation. Thermal resistance network, Boundary Conditions, Effect of variable thermal conductivity for one-dimensional steady-state conduction in a plane wall. The critical radius of insulation.

UNIT-II

Fins: Heat transfer analysis of a body with negligible internal temperature gradients, fins efficiency and effectiveness.

Lumped system analysis within the body with negligible internal temperature gradients. **Transient** heat transfer analysis of an infinite slab with specified temperature and connective boundary conditions. Use of Grover & Heisler charts for solving problems of infinite slabs, cylinders, spheres.

UNIT-III

Convection: Physical mechanism of convection, Buckingham pi-theorem and use of dimensional analysis in free and forced convection, Physical significance of different dimensionless numbers. Concept of velocity boundary layer, thermal boundary layer.
Reynolds analogy, Chilton-Colburn analogy for turbulent flow over flat surfaces. Calculation of heat transfer for flow over plates, cylinders and in pipes in free and forced convection using empirical formulae.

UNIT-IV

Radiation: Concept of a blackbody,Absorptivity, Reflectivity, and Transmissivity. Emissivity, the Planck Distribution law, Wien's Displacement Law, Stefan-Boltzmann, Kirchhoff's Law. The View factor, View factor relations, View Factors between Infinitely Long Surfaces: The Crossed-Strings
Method, Radiation exchange between Opaque, Diffuse, Gray Surfaces in an enclosure: Blackbody radiation exchange, the two-surface enclosure, radiation shields.

UNIT-V

Heat Exchangers: Heat exchanger types, overall heat transfer coefficient. Heat exchanger analysis: Use of the Log Mean Temperature Difference (Parallel-Flow, Counter-Flow), the Effectiveness–NTU Method. Heat Exchanger Design and Performance Calculations (LMTD, ε-NTU methods), Selection of heat exchangers.
Boiling: Pool boiling regimes, nucleate pool boiling, and critical heat flux for nucleate pool boiling, minimum heat flux.
Condensation: Physical Mechanisms, Laminar Film Condensation on a Vertical Plate, Turbulent Film Condensation, dropwise condensation.

Suggested Reading:

1. John H Lienhard IV, John H Lienhard V,A"Heat Transfer" Textbook, Fifth Edition, Phlogiston Press, 2019.
2. Theodore L. Bergman, Adrienne S. Lavine, Frank P. Incropera, David P. DeWitt "Fundamentals of Heat and Mass Transfer", 8th Edition, John willey& Sons, 2018.
3. J.P. Holman, "Heat Transfer", Tenth Edition, McGraw Hill Companies Inc., 2010.
4. Yunus A Cengel, "Heat Transfer A Practical Approach", Second Edition, McGraw-Hill, 2002.
5. James R. Welty, Charles Wicks, Robert Wilson, Gregory Rorrer, "Fundamentals of Momentum, Heat and Mass Transfer", 4th Edition, John Wiley and Sons Ltd, 2001.

Course Code	Course Title						Course Type
PC504ME	**MACHINE DESIGN**						**Core**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

Course Objectives:

- Importance of materials & criteria of failure of general mechanical components like springs, gears, brakes, bearings used in industry
- Importance of the stresses developed under different loading conditions
- Learn to apply design procedures for mechanical components like springs, gears, bearings
- Learn to evaluate the design procedure based on failure theories
- Learn to design components for new applications

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Identify and classify various materials & the corresponding failure theories to be applied in the design of simple mechanical components like springs, gears, bearings, IC engines.
2. Illustrate various mechanical components under different loading conditions & constraints.
3. Analyse various mechanical components under simple and combined loads.
4. Determine (material, dimensions, shape, number) mechanical components subjected to various types of loads, constraints & failure criterions.
5. Design mechanical components for specific applications in industry.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	3	3	2	1	-	-	-	1	-	-	1	2	1
CO2	3	2	3	2	1	-	-	-	1	-	-	1	2	1
CO3	2	2	3	2	1	-	-	-	1	-	-	1	2	1
CO4	3	2	3	2	1	-	-	-	1	-	-	1	2	1
CO5	2	2	3	2	1	-	-	-	1	-	-	1	2	1

UNIT-I

Mechanical springs: Introduction. Different types of springs. Materials used for springs. Helical Springs: Whal factor, calculation of stress, Deflection and energy stored in spring. Design for static and fluctuating loads. Leaf Springs: Stress and Deflection. Nipping of Leaf springs. Design for static and fluctuating loads.

UNIT-II

Gears: Introduction of gear drives, different types of gears, Materials used for gears. Standards for gears and specifications. Spur Gear Design: Basic analysis of gear Tooth-Bending Stress-Lewis equation, refined analysis of gear tooth -bending strength-procedure, gear tooth surface fatigue analysis-procedure, spur gear design procedures, Design of Helical, Bevel and Worm gears, concepts of Design for manufacturability.

UNIT-III

Bearings: Introduction. Materials used for Bearings. Classification of bearings and mounting of bearings.
Design of sliding contact bearings: Properties and types of Lubricants, Design of Hydrostatic and Hydrodynamic sliding contact bearings.
Design of Rolling Contact Bearings: Different types of rolling element bearings and their constructional details, static load carrying capacity. Dynamic load carrying capacity. Load-life relationship, selection of bearing life. Design for cyclic loads and speeds. Selection of Ball and Roller bearings.

UNIT-IV
I.C. Engine parts: Introduction. Materials used. Design of piston, connecting rod and crank for I.C. Engines. Fly wheels: Introduction. Design of solid disk type and rimmed fly wheels. Design of Brakes, Block brake with short shoe & long shoe, Pivoted block brake with long shoe, band brakes, disc brakes, internal expanding shoe, thermal considerations.

UNIT-V
Design of curved beams: Introduction stresses in curved beams, expression for radius of curvature of neutral axis for rectangular, circular, trapezoidal and T-sections. Design of crane Hook, C-clamp. Design of chain drives: Power rating of roller chains. Strength of roller chains.

Suggested Reading:
1. Bhandari V.B. “Machine Design”, Tata Mc Graw Hill Publications, 1994.
2. Robert C. Juvinall, Kurt M. Marshek, “Fundamentals of Machine Component Design”, Wiley publications, 5th edition, 2012.
3. J.E. Shigley , C.R. Misckhe, “Mechanical Engineering Design”, Tata Mc Graw Hill Publication, 2003.
4. M.F. Spotts, “Design of Machine Elements”, Prentice Hall, 1964.
5. Robert L. Norton, “Machine Design: An Integrated Approach”,2/e PearsonEducation, 2000.

Course Code	Course Title					Course Type	
PC505ME	**METAL CUTTING AND MACHINE TOOLS**						**Core**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To learn the geometry and mechanics of metal cutting for turning, drilling milling and tool materials.
- To understand the heat distribution, tool wear and tool life
- To know the various machining processes such as lathe, drilling, milling, boring, broaching, grinding etc.
- To know various types of work and tool holding devices for conventional machining.
- To understand the basics of Unconventional Machining processes.

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Develop the relations for shear angle, shear strain, forces and temperatures associated with orthogonal cutting.
2. Select the cutting fluids, tool materials and coatings to control the tool wear and temperature.
3. Evaluate the tool life and economics of machining for maximum production and minimum cost.
4. Select the appropriate machine tool and tool & work holding devices for machining of components.
5. Illustrate the various finishing techniques and unconventional machining processes.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	2	2	-	-	1	-	-	-	-	1	1	2
CO2	3	2	2	1	-	-	-	-	-	-	-	-	1	-
CO3	3	2	2	1	-	-	-	-	-	-	-	-	2	-
CO4	3	2	2	2	-	-	-	-	2	-	-	-	-	1
CO5	3	2	2	1	-	2	-	-	2	-	-	1	1	2

UNIT-I

Basic chip formation process. Tool geometry: Nomenclature of single point cutting tool by ASA, ORS and NRS. Geometry of drills, Milling cutters and broaches. Recommended Tool angles. Chip formation: Types of chips, BUE, Chip breakers. Machining: Orthogonal and oblique cutting, Mechanics of Orthogonal Cutting: Merchant's analysis, Friction. Shear angle: Shear angle Solutions of Merchant and Lee & Shafer. Cutting tool materials: High carbon steel, HSS, Carbides, Ceramics, Coated carbides, Cermets, HPC, cBN & Diamond.

UNIT-II

Measurement of Cutting Forces: Lathe tool dynamometers, Drilling, Milling and Grinding Dynamometers. Thermal aspects of metal cutting: Sources of heat and heat distribution, various methods of measurement of temperature, Cutting fluids and applications. Tool wear, Tool life &**Machinability:** Types of wear, mechanism of tool wear, Tool life & Machinability. Effects of process parameters on Tool life, Taylor's tool life equation. Economics of machining: Tool life for maximum production, minimum cost.

UNIT-III

Constructional features and specifications of machine tools: Various operations on Lathe, Types of Lathes and special attachments on a Centre Lathe. Drilling, Milling operations. Indexing methods. Shaper, planer and slotter and their differences. Quick return mechanisms, Automatic feed devices. Jig Boring machines- Differences between horizontal and vertical jig boring machines. Principles of Broaching.

UNIT- IV

Abrasive Processes: Grinding machines. Types of grinding, Abrasives and bonds used for grinding wheels. Specification and selection of wheels. Lapping, Honing, Polishing, Buffing, Super finishing and burnishing.

Screws and gear manufacturing: Screw making by tapping, Chasers, Thread rolling, Thread milling, Thread grinding. Gear shaping, Gear hobbing, Gear shaving and grinding.

UNIT-V

Jigs and Fixtures: Design principles for location and clamping. Tool holding and work holding devices.Quick clamping devices. Types of Jigs and fixtures.

Unconventional machining: Principles of working and applications of USM, AJM, WJM, EDM, ECM,LBM, EBM and PAM.

Suggested Reading:

1. David A. Stephenson, Johs S. Agapiou, “Metal Cutting Theory and Practice”, CRC Press, 3rd Edition, 2016.
2. B.L. Juneja,Shekhon G.S. and Seth Nitin, “Fundamentals of Metal Cutting & Machine tools”, New Age Publishers, 2003.
3. Amitabha Ghosh and Ashok Kumar Mallik, “Manufacturing Science”, Affiliated East-West Press Pvt. Ltd., 2ndEdition, 2010.
4. Winston A. Knight and Geoffrey Boothroyd, “Fundamentals of Metal Machining & Machine tools”, CRC Press, 3rd Edition, 2005.
5. McGeough JA, “Advanced Methods of Machining”, Chapman & Hall, 1988.

Course Code	Course Title						Course Type
PE511ME	**PRODUCTION PLANNING AND CONTROL**						**Professional Elective -I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

Course Objectives:

1. To understand the importance of PPC in an organization and the role of forecasting in PPC
2. To learn the role of inventory management in PPC and various inventory control techniques
3. To understand the concepts of routing and scheduling
4. To understand the objectives of line balancing and aggregate planning
5. To know the meaning of dispatching and various types of dispatching techniques.

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Identify the objectives, functions, applications of PPC and forecasting techniques.
2. Apply different Inventory Control Techniques for determining the optimum inventory.
3. Solve routing and scheduling problems.
4. Illustrate various types of Line Balancing Techniques and Aggregate Planning Strategies.
5. Identify various types of dispatching techniques.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	2	-	-	-	1	-	-	-	-	1	1	-	1
CO2	2	2	2	-	-	1	-	-	-	-	2	1	-	-
CO3	2	2	2	-	-	-	-	-	-	-	1	1	-	1
CO4	2	2	-	-	-	-	-	-	-	-	1	1	-	1
CO5	2	2	-	-	-	-	-	-	-	-	-	1	-	-

UNIT-I

Definition and Objectives of production Planning and Control – Functions of production planning and control – Elements of production control – Types of production – Organization of production planning and control department – Internal organization of department. Forecasting: Importance of forecasting – Types of forecasting, their uses –General principles of Forecasting –Forecasting techniques– qualitative methods- Jury/Expert Method, Survey of Expert opinion method, Sales force composite method, Survey of buyer's intention method and quantitative Methods-Simple average, moving average, smoothing coefficient, Least Square method.

UNIT-II

Inventory Management: Functions of inventories – relevant inventory costs – ABC analysis – VED analysis – EOQ model – Inventory control systems – P–Systems and Q-Systems Introduction to MRP-I, MRP-II & ERP, JIT inventory, Kanban system

UNIT-III

Routing & Scheduling: Definition of Routing – Routing procedure –Route sheets – Bill of material – Factors affecting routing procedure. Definition of Scheduling – Activities- Difference with loading, Scheduling types: Forward, Backward scheduling, Job shop scheduling methods – Arrival pattern, processing pattern, number of workers available, machine varieties available, Priority rules for job sequencing FIFO, SPT, SOT, EDD, STR, CR, LISO, Random Orders. Scheduling Techniques Gantt Charts, LOB, Johnson's job sequencing rules-n jobs on 2machines, n jobs on 3 machines, n jobs on m machines.

UNIT-IV

Line Balancing & Aggregate Planning:Introduction to line balancing, objectives, terms related to line balancing, procedures, simple problems; Introduction to Aggregate Planning, Inputs to aggregate planning, strategies- Line strategy, chase strategy, capacity options, demand options.

UNIT-V

Dispatching: Centralized and Decentralized Dispatching- Activities of dispatcher – Dispatching procedure – follow-up – definition – Reason for existence of functions – types of follow up, applications of computer in production planning and control.

Suggested Readings:

1. Samuel Eilon, "Elements of Production Planning and Control", Universal PublishingCorporation,1991.
2. Buffa & Rakesh Sarin, "Modern Production & Operations management", 8th edition, Wiley india Pvt. Ltd, 2009.
3. S.N. Chary, "Production & Operations Management", 6th Edition, McGraw-Hill Education, 2019.
4. Krajewski, L.J., and Ritzman, L. P., "Operations management – strategy and analysis", 6th Edition,Prentice-Hall of India Pvt. Ltd, 2003.
5. S.K Sharma, savita Sharma, "Industrial Engineering and Operations Management", Sk Kataria&Sons, 2002.

Course Code	Course Title						Course Type
PE512ME	**THEORY OF ELASTICITY**						**Professional Elective -I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To familiarize stress and strain.
- To distinguish plane stress and plane strain analysis.
- To understand problems on bending, torsion, thin wall, thick wall and columns.

Course Outcomes: Upon successful completion of this course, the student will be able to:

- Illustrate the basic concepts in continuum mechanics of solids, including of strain, internal force, stress and equilibrium in solids.
- Implementation of energy principles in solution of strength of materials problems.
- Derivation of constitutive relations of plane stress and strain.
- Derivation of stress-strain relations for linearly elastic solids such as beams and plates, and Torsion of shafts.
- Analyze axisymmetric problems such as cylinders and rotating discs and stability of columns.
-

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	3	-	-	-	-	-	-	-	1	3	3
CO2	3	3	3	2	-	-	-	-	-	-	-	2	3	3
CO3	3	3	3	3	-	-	-	-	-	-	-	2	3	2
CO4	3	3	2	2	-	-	-	-	-	-	-	2	3	2
CO5	3	3	2	2	-	-	-	-	-	-	-	2	3	2

UNIT-I

Analysis of Stress: Stress tensor, Equilibrium equations in Cartesian coordinates, Two dimensional stress at a point and principal stresses. Three dimensional stress at a point and principal stresses. Stresses on an oblique plane in terms of principal stresses

UNIT-II

Analysis of Strain: Strains in terms of compatibility, Generalized Hook‟s Law distortional energy, St. Venant‟s principle.displacements in Cartesian coordinates, Equations of and Lame‟s constants, Strain energy, Dilatational and

UNIT-III

Two dimensional problems: Plane stress, Plane strain problems: Stress function, Bi-harmonic equation,Equilibrium equations, Strain displacement relations and compatibility equations in polar coordinates,Stress concentration.

UNIT-IV

Bending of straight beams and curved beams. Torsion of shafts, Membrane analogy. Bending of plates.

UNIT-V

Axi-symmetric problems, Thick walled cylinders subjected to internal and external pressures, Stresses in composite tubes, Rotating disks of uniform and variable thickness. General treatment of column stability problems.

Suggested Reading:

1. L.S. Srinath, "Advanced Mechanics of Solids", Tata McGraw Hill Publ. Co., 1970.
2. S. Timeshenko & J.N. Goodier, "Theory of Elasticity", Tata McGraw Hill, 1970.
3. A.C. Uguaral, "Advanced Strength and Theory of Elasticity", Elsevier Publication, 1965.
4. S. Singh, "Theory of Elasticity", Khanna Publishers, 1979.
5. Teodor M. Atanackovic, Ardeshir Guran, Theory of Elasticity for Scientists and Engineers, Birkhäuser Boston, 2012.

Course Code	Course Title							Course Type
PE513ME	**SUSTAINABLE ENERGY TECHNOLOGIES**							**Professional Elective -I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Outcomes:

1. Understand the concept of energy and its sustainable energy opportunities and resources of the energy.
2. Acquire in-depth knowledge on wind energy and power generation
3. Understand the importance of solar energy conversion technologies for power generation.
4. Realization of global bioenergy potential and scenario of bioenergy in India, biomass conversion technologies.
5. Gain the knowledge of Ocean thermal energy technologies.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	1	-	-	-	-	-	-	-	-	1	-	-
CO2	3	2	2	1	1	-	1	-	-	-	-	1	1	1
CO3	3	2	2	2	-	1	1	-	-	-	-	1	1	1
CO4	3	2	2	2	1	1	1	-	-	-	-	1	1	1
CO5	3	2	2	1	1	-	1	-	-	-	-	1	1	-

-

UNIT-I

Introduction to Energy Fundamentals: Sustainability Definitions, Principle of sustainability design, engineering, system analysis, Sustainability challenges and opportunities.

UNIT-II

Introduction, Wind Power Energy, Basics of Wind Power Turbine Operation, Energy Generation Capacity of a Wind Turbine, Construction of Wind Turbines, Wind Power Calculations, Advantages and Disadvantages of Wind Power.

UNIT-III

A Brief History of the Photoelectric Phenomenon, Types of Solar Cells, Solar Panel Arrays, Solar Power System Components and Materials, Solar Power System Configuration and Classifications, Storage Battery Technologies, Small-Scale Solar Power Pumping, Designing a Typical Residential Solar Power System,PV and BIPV Technologies, Commercial Applications.

UNIT-IV

Introduction to Biomass Resources, Potential of bioenergy, Composition of Biomass, Biomass Conversion Techniques- Wet Process, Dry Process, Types of Biomass Fuels, Biomass power generation. Biofuels for a sustainable future: Bioethanol, Biodiesel.

UNIT-V

Ocean Thermal Energy Conversion (OTEC):Principle- Lambert Law of absorption - Open and Closed OTEC Cycles -Major problems andoperational experience.
Tidal energy: Tide – Spring tide, Neap tide – Tidalrange – Tidal Power – Types of Tidal power plant

Suggested Reading:

1. Peter Gevorkian, Ph.D., PE, Sustainable Energy Systems Engineering: The Complete Green Building Design Resource, 1st Edition, McGraw-Hill Education, 2007.
2. Mehmet Kanoğlu,Yunus A. Çengel, John M. Cimbala, Fundamentals and Applications of Renewable Energy, 2nd Edition, McGrawHills, 2023.
3. D.P. Kothari, K.C. Singal, Rakesh Ranjan, Renewable Energy Sources and Emerging Technologies, 3rd Edition, PHI Learning, 2022.
4. Bob Everett, Stephen Peake, James Warren, Energy Systems and Sustainability, 3rd Edition, OUP Oxford.
5. R. O'Hayre, S-W. Cha, W. Colella, F. B. Prinz, Fuel Cell Fundamentals, John Wiley and Sons, USA, 2005.

Course Code	Course Title							Course Type
PE514ME	NANOMATERIALS AND TECHNOLOGY							Professional Elective -I
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	T	D	P		CIE	SEE	
	3	-	-	-	3	40	60	3

Course Objectives:

- Understand the influence of dimensionality of the object at nanoscale on their properties;
- Aware of size and shape controlled synthesis of nanomaterial's and Fabrication.

Course Outcomes: After completion of the course student will be able to

- Understand the science of nanomaterials and technology.
- Understand Nano structures, fabrication and special Nano materials.
- Understand the different methods of synthesis of nonmaterial
- Understand fabrication techniques of nanomaterials

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	1	1	-	-	-	-	-	1	-	-	2	1
CO2	3	2	1	1	-	-	-	-	-	1	-	-	2	1
CO3	2	2	2	1	-	1	-	-	-	1	-	-	2	2
CO4	2	2	2	1	-	-	-	-	-	1	-	-	2	2
CO5	2	2	1	1	-	1	-	-	-	1	-	-	-	2

UNIT-I

Introduction: Nanoscale, Properties at Nanoscale, advantages and disadvantages, importance of Nano Technology, Bottom-up and Top-down approaches, challenges in Nano Technology. Metal Nanocrystals, Semiconductor nanomaterials, Carbon nano tubes.

UNIT-II

Materials of Nano Technology: Introduction-Si-based materials, Ge-based materials, Smart materials, metals, Ferroelectric materials, Polymer materials, GaAs & InP (III-V) group materials, Nano tribology and Materials, Principles and analytical techniques of XRD, SEM, TEM and STM/AFM

UNIT-III

Nano Structures: Zero dimensional Nano structure (Nano Particles)- Synthesis procedure, characterization techniques, properties and applications of Nano Particles. One dimensional Nano structures (Nano Wires, Nano Tubes)- Various Synthesis procedure, characterization procedure and principles involved, properties and applications of Nano Wires, Types of Nano Tubes, Synthesis procedure, characterization properties and applications of Nano Tubes.

UNIT-IV

Synthesis of nanomaterials:

Physical Methods: Physcal Vapour Deposition (PVD), Inert gas condensation, Arc discharge, DC sputtering, Ion sputtering, Ball Milling, Molecular beam epitaxy, Electro-deposition,

Chemical Methods: Metal nanocrystals by reduction, Sol- gel, Solvothermal synthesis, Photochemical synthesis, Electrochemical synthesis, Nanocrystals of semiconductors/

UNIT-V

Nano Fabrication: Introduction, Basic fabrication techniques (Lithography, thin film deposition, and doping) MEMS fabrication techniques, Nano fabrication techniques (E-beam Nano-imprint fabrication, Epitaxy and strain engineering, Scanned probe techniques).

Suggested Reading:

1. A.K.Bandyopadyay, Nano Materials, New Age Publications, 2007.
2. T. Pradeep, Nano: The Essentials: Understanding Nanoscience and Nanotechnolgy, Tata McGraw-Hill, 2008.
3. Carl. C. Koch, Nano Materials Synthesis, Properties and Applications, Jaico Publishing House, 2008.
4. Willia Illsey Atkinson, NanoTechnology, Jaico Publishing House, 2009.
5. Introduction to Nanotechnology by Charles P. Poole, Jr., Frank J. Owens
6. Nanostructure and Nanomaterials: Synthesis, Properties and Application by G. Cao, Imperial College Press, 2004.

Course Code	Course Title						Course Type
PC551ME	**FLUID MECHANICS AND HYDRAULIC MACHINES LABORATORY**						**Core**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	-	**-**	**-**	**2**	**3**	**25** / **50**	**1**

Course Objectives:

- The course should enable the students:
- To understand general governing equations for various fluid flows
- To enrich the concept of fluid mechanics and hydraulic machines.
- To demonstrate the classical experiments in fluid mechanics and hydraulic machinery.
- To understand the functioning of various flow measuring devices, pumps and turbines
- To evaluate the performance characteristics of turbines and pumps

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Illustrate the working of Hydraulic machines.
2. Apply the Bernoulli‟s principle in flow measurement used in hydraulic machines.
3. Analyze working principles of hydraulic pumps and turbines.
4. Evaluate the theoretical concepts and apply them in the functioning of hydraulic machines
5. Estimate the performance of pumps and turbines.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	1		1	1	1	3	3	3	1	1	1	
CO2	3	3	3		1	1	1	3	3	3	1	1	1	
CO3	3	3	3		1	1	1	3	3	3	1	1	1	
CO4	3	2	2		1	1	1	3	3	3	1	2	1	1
CO5	3	3	3		1	1	1	3	3	3	1	2	1	1

List of Experiments:

1. Determination of Cd and Cv of an orifice meter
2. Calibration of a mouth piece
3. Calibration of a Venturi meter
4. Verification of Bernoulli‟s principle
5. Performance test on Pelton wheel turbine
6. Characteristic curves test on Pelton wheel turbine
7. Performance test on Turgo wheel
8. Characteristic curves test on Turgo wheel
9. Performance test on Francis turbine
10. Characteristic curves test on Francis turbine
11. Performance test on reciprocating pump
12. Study of positive displacement and Rotodynamic pumps with the help of models.
13. Study of the working of Kaplan turbine

Course Code	Course Title						Course Type
PC552ME	**DYNAMICS OF MACHINES LABORATORY**						**Core**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	-	**-**	**-**	**2**	**3**	**25** / **50**	**1**

Course Objectives:

- Carry out the kinematic and dynamic analysis of planar and spatial mechanisms
- Find out natural frequencies, forced frequencies and other important parameters for different vibrating systems using Universal vibration apparatus.
- Perform modal analysis of vibrating systems
- Study the working of gyroscope and governors
- Effects of rotary unbalancing and methods of reduction

Course Outcomes:

1. Importance of vibrations in mechanical systems & analyse Single and multi-degree freedom vibrating systems.
2. Inspect methods to reduce effects of static and dynamic unbalance due to rotating systems. machines.
3. Investigate the effect of various governors on speed control of mechanisms.
4. Evaluate the reaction torque due to gyroscopic effects in systems.
5. Carry out the kinematic and dynamic analysis of planar and spatial mechanisms.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	1	1	1	1	2	1		3	3	3	1	1	1	1
CO2	1	1	1	1	2	1		3	3	3	1	1	1	1
CO3	1	1		1	1	1		3	3	3	1	1		1
CO4	1	1	1	1	2	1		3	3	3	1	1	1	1
CO5	1	1	2	1	3	1		3	3	3	1	1	2	1

List of Experiments:

1. To determine experimentally, the Mass Moment of Inertia of a Flywheel and Axle and compare with theoretical value.
2. To verify the formula of a Simple Pendulum and to show that the time period is independent of the mass of the bob.
3. To determine the radius of gyration "K" of given compound pendulum.
4. To find the damping coefficient(c), damping ratio (ξ) and logarithmic decrement (δ) of damped longitudinal vibrations of spring mass system.
5. To study the Torsional vibration (undamped) of single Rotor Shaft system.
6. To study the free Torsional vibrations of two rotor system and to determine the frequency of vibration theoretically and experimentally.
7. To study the response of a beam under forced oscillations and compare the experimental response with theoretical for resonance frequency.
8. To determine critical speed or whirling speed of a rotating shaft and to verify the value theoretically.

9. To verify the law of gyroscopic couple, = with the help of motorized Gyroscope calibrate the gyroscope.
10. To determine Centrifugal Forces of the Governor and Plot the Characteristic Curves of the governor.
11. To balance the given unbalanced rotating masses by drawing force polygon and couple polygon.
12. To find the natural and damped frequency of an Aluminium cantilever beam in transverse vibrations.
13. Determination of natural frequency of transverse vibration in a given aluminium rod with concentrated weights at two places using Dunkerley method
14. To determine the radius of gyration L and thereby determining the mass moment of inertia of a connecting rod.
15. Modal analysis of a composite beam.
16. Simulation experiments on Kinematic and dynamic analysis of mechanisms and systems using.

MSC Adams software

- Analysis of Freely falling body, Body moving up the slope, Simple pendulum, Linear spring, and Non-linear spring

Simulation of kinematic and dynamic analysis of:

- Four bar Mechanisms, Slider crank Mechanisms, Spur Gear Analysis, Multi-link robots, Cam Mechanisms and Rope and Chain drive systems
- Note: At least 10 experiments (08 hardware+02 software) from the set of above experiments needs to be conducted by each student.

Suggested Reading:

1. MSC Adams 2013.2 User Guide
2. Universal Vibration Apparatus User Manual (KC Engineers)
3. Static & Dynamic balancing of rotating masses, user manual (KC Engineers)
4. Gyroscope apparatus User Manual (KC Engineers)
5. Centrifugal Governors User Manual (KC Engineers)

SCHEME OF INSTRUCTION EXAMINATION
B.E VI Semester (Mechanical Engineering)

S.No.	Course Code	Course Title	Scheme of Instruction			Contact hrs/wk	Scheme of Examination		Credits
			L	T	P		CIE	SEE	
1	**PC601ME**	Control System Theory	3	0	0	3	40	60	3
2	**PC602ME**	Metrology and Instrumentation	3	0	0	3	40	60	3
3	**PC603ME**	Refrigeration and Air Conditioning	3	0	0	3	40	60	3
4	**PC604ME**	Principles of Management	3	0	0	3	40	60	3
5	**Professional Elective – II**		3	0	0	3	40	60	3
6	**Professional Elective – III**		3	0	0	3	40	60	3
7	**Open Elective – I**		3	0	0	3	40	60	3
PRACTICALS									
8	**PC 651ME**	Metal Cutting and Metrology Lab	-	-	2	2	25	50	1
9	**PC 652ME**	Computer Aided Engineering Lab	-	-	2	2	25	50	1
10	**PC 653ME**	Mini Project	**-**	**-**	**6**	**6**	**50**	**-**	**3**
Total			**21**	**0**	**10**	**31**	**380**	**520**	**26**

Course Code	Professional Elective - II
PE621ME	Finite Element Analysis
PE622ME	Additive Manufacturing Technologies
PE623ME	Non- Conventional Machining and Forming methods
PE624ME	Non Destructive Testing
PE625ME	Design of Solar Energy systems
PE626ME	Energy Storage and Management System
PE627ME	Machine Learning application
PC604CS	Deep Learning

Course Code	Professional Elective - III
PE631ME	Computational Fluid Flows
PE632ME	Cryogenic Technology
PE633ME	Machine Tool Engineering and Design
PE634ME	Total Quality Management
PE635ME	Fatigue Creep and Fracture
PE636ME	Advanced Propulsion and Space Science
PE637ME	Mechatronics Systems
PE638ME	Virtual Reality and Augmented Reality

Course Corse	Open Elective-I
OE601CE	Disaster Management
OE602CE	Road safety Engineering
OE601ME	3D Printing Technology
OE602ME	Finite Element Method
OE601EE	Applications of Electrical Energy
OE602EE	Electrical Safety Management
OE601EC	Principles of Electronic Communication Systems
OE602EC	Verilog HDL
OE601BM	Engineering Applications in Medicine
OE602BM	Human Assistive Technologies
OE601CS	Python Programming
OE602CS	Cyber Security

Course Code	Course Title						Course Type
PC601ME	**CONTROL SYSTEMS THEORY**						**Core**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

Course Objectives:

- To introduce students to the fundamental of feedback control system theory and use of analytical design methods in designing, analyzing various physical systems and to apply the gained knowledge in developing solutions for real world systems.
- To develop the ability of formulating mathematical models and designing feedback control systems.
- To provide students with necessary tools to analyze linear feedback control systems.
- To introduce the students to the concepts of digital control and modern control.

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Distinguish between open loop and closed systems with examples.
2. Develop mathematical models of mechanical, electrical, electro-mechanical systems.
3. Evaluate the effects of transient and steady state responses and apply these models to real time systems.
4. Apply the time response and frequency response methods to determine the stability of the system.
5. Apply the concepts of discrete time control systems. Analyse and design multi input, multi output systems by state space analysis.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	1	1	-	-	-	-	-	-	1	1	1
CO2	3	3	2	1	1	-	-	-	-	-	-	1	1	1
CO3	3	3	2	1	1	-	-	-	-	-	-	1	1	1
CO4	3	3	2	1	1	-	-	-	-	-	-	1	1	1
CO5	3	2	2	1	1	-	-	-	-	-	-	-	1	1

UNIT-I

Introduction: Classification of control systems. Examples of control systems with applications in Mechanical Engineering. Relationships of components and analogies. Performance characteristics of control system components. Hydraulic and pneumatic control systems. Methods of analysis using standard input functions. Laplace transformation, use of transfer functions.

Derivation of system equations: The simultaneous equation method. Block diagram method and Laplace transform approach. Error sensing devices: Potentiometer, synchros, and AC-DC servomotors, Encoders, Decoders.

UNIT-II

Modeling in the time domain. Time Response: Response characteristics of systems Types of input. Transient response of first and second order system for step input. Time domain specification. Types of system, static error coefficients, error series, Routh-Hurwitz criterion of stability.

Root Locus Techniques: Typical systems analyzed by Root Locus Techniques. Effect of location of roots on the system response.

UNIT-III

Modeling in the frequency domain. Frequency response analysis: The frequency response of a second order system, effect of numerator factors, zero factors in a transfer function. Bode plots, Gain-Phase plot, Nyquist criterion for stability, Gain Margin and Phase Margin, compensation techniques.

UNIT-IV

Discrete Control Analysis: The Z-transformation, digital control, advantages and disadvantages, Digital control system architecture. The discrete transfer function. Z-domain stability. Stability tests. Jury's stability criteria.

UNIT-V

State space representation: Concept of state. State variable, state models of linear time invariantsystems, derivation of state model from transfer functions and differential equations.

State transition matrix, solution of state equations by time domain method.

Suggested Reading:

1. Katsuhiko Ogata, “Modern Control Engineering”, Prentice hall, 5th edition, 2010.
2. Norman S Nise, Control system engineering‟, Wiley publications, 6th edition, 2010.
3. Francis Raven H. "Automatic Control Engineering", Tata McGraw Hill, 5th Edition, 1995.
4. Peter Dransfield, "Engineering Systems and Automatic Control", Prentice Hall of India, 1974.
5. Gene F. Franklin, J. David Powell, Abbas Emamin Naini, "Feedback control of Dynamic Systems", Pearson Education Pvt. Ltd., 4th Edition, 2004.

Additional Readings

1 Benjamin kuo, “Automatic control systems”, 9th Edition, Wiley, India, 2010.

Course Code	Course Title						Course Type
PC602ME	**METROLOGY AND INSTRUMENTATION**						**Core**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

Course Objectives:

- To familiarize with limits and Fits, ISO system and the instruments used to measure these limits.
- To have knowledge of various precision linear and angular measuring instruments
- To learn the importance of form and how to measure form errors
- To understand the working principles of various instrument used for the measurement of strain, pressure, temperature and vibrations.

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. To familiarize with ISO system of limits and fits and the precisiom instruments used for linear, angular measurements
2. Understand the construction details of precision measurement machines used in industries
3. Use contact and non contact gauges for G.D and tolerance measurement
4. Calibrate various strain and displacement measuring instruments
5. Recommend various instruments used for measuring force, pressure, temperature , vibrations .

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	2	-	1	-	-	-	-	-	1	1	2	2
CO2	3	3	2	2	1	-	-	-	-	-	1	1	2	2
CO3	3	3	2	2	1	3	-	-	-	-	1	1	2	2
CO4	3	3	2	2	1	3	-	-	-	-	1	1	2	2
CO5	3	3	3	2	1	-	-	-	-	-	1	1	2	2

UNIT-I

Limits and Fits, I.S.O. system. Types of interchangeability. Slip gauges and end bars. Height gauges, Abbe's rule, Types of micrometers. Tomlinson gauges, sine bar, autocollimator, calibration of precision polygons and circular scales. Dial indicator, Sigma mechanical comparator. Free flow and back pressure type Pneumatic comparators. Contact & non-contact tooling, Applications of single and multi-jet gauge heads; computation and match gauging.

UNIT-II

Optical projector-measurement by comparison, movement and translation, chart gauge types and micro gauge bridge lines. Tool maker's microscope, Floating carriage diameter measuring machine and Coordinate Measuring Machine. Measurement of straightness & flatness using autocollimator. Roundness measurement with intrinsic datum (V-block, Bench centers) and extrinsic datum (TALYROND).

UNIT-III

Taylor's principles for plain limit gauges. Usage and limitations of Ring and Snap gauges. Indicating type limit gauges. Position and receiver gauges, principles of thread gauging. Gauge materials and steps in gauge manufacture. General geometrical tests for machine tools. Surface roughness characteristics and its measurement. Elements of instrumentation system. Static characteristics, Systematic and random errors. Dynamic response of first and second order instruments.

UNIT-IV

Strain Measurement: Wire and foil type resistance strain gauges, Evaluation of principal strains with Rosette gauges. Desirable characteristics of gauge material, backing material and adhesive. Ballast and bridge circuits. Lead resistance compensation. Adjacent arm and self-temperature compensating methods. Strain gauge calibration. Strain gauge circuits for measuring axial load, bending load and torque.

Measurement of displacement with LVDT and Lasers interferometry.

UNIT-V

Force Measurement: Proving ring, Strain gauge load cells, Piezo-electric load cell, Ballastic weighing, Pneumatic and hydraulic force meters. Pressure Measurement: Thermocouple vacuum gauge, High and Low pressure measuring devices. Pirani gauge, Bourdon gauge and Bulk modulus gauge, calibration methods.

Vibration measurement, accelerometers, vibration exciters, calibration of vibrometers. Temperature measurement: Laws of thermo electricity, types of materials and junctions used in thermocouples, lead and extension wires, ambient temperature compensation, protection tubes, series and parallel circuits. RTD. Total radiation and Optical Pyrometers.

Suggested Reading:

1. R.K. Jain, "Engineering Metrology", Khanna Publications, 1996.
2. I.C. Gupta, "A text book of Engineering Metrology", Dhanpat Rai & Sons, 1984.
3. Bechwith, Marangoni, Lienhard, "Mechanical Measurement", LPE; Pearson Education Asia 2000.
4. D.S. Kumar, "Mechanical Measurements", Metropolitan Book Co., New Delhi, 2001.
5. Rega Rajendra, "Principles of Engineering Metrology", Jaico Publishing House, Mumbai, 2008.

Course Code	Course Title						Course Type
PC603ME	**REFRIGERATION AND AIR CONDITIONING**						**Core**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

Course Objectives:

- To understand the basic concepts of refrigeration and air conditioning systems.
- To study the different methods of refrigeration system and their performance.
- To understand conventional and non-conventional refrigeration system.
- To study the psychrometric terms and psychrometric processes.
- To study the lower temperature applications: cryogenics by using cascade systems.

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Distinguish different types of refrigerants and their properties used in the refrigeration cycle.
2. Analyze the performance of vapour compression and vapour absorption system.
3. Distinguish between conventional and non-conventional refrigeration system.
4. Apply the principles of Psychrometrics to estimate the air conditioning loads for the industrial applications.
5. Illustrate various methods to obtain cryogenic temperatures.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	2	-	2	2	-	-	-	-	-	3	-
CO2	3	3	2	1	-	2	2	-	-	-	-	-	2	-
CO3	3	3	2	1	-	-	-	-	-	-	-	-	2	-
CO4	3	3	2	1	-	1	1	-	-	-	-	-	2	-
CO5	3	2	1	1	-	1	1	-	-	-	-	-	2	-

UNIT-I

Definition of Refrigeration & Air Conditioning. Necessity of refrigeration. Applications of refrigeration and air conditioning. Units of refrigeration. Refrigerants classification and desirable properties of refrigerants. Air refrigeration: Carnot refrigeration cycle and its limitation. Air refrigeration cycle operating on Brayton cycle and analysis. Aircraft refrigeration: Necessity.

Advantages of using air cycles for aircraft refrigeration. Refrigeration systems for low and high speed aircrafts.

UNIT-II

Vapour compression system: Simple vapour compression cycle: COP, representation of cycle on T- S, P-H and H-S diagrams. Actual vapour compression cycle. Effect of superheating and sub cooling– problems.

Vapour absorption refrigeration systems: Ammonia –water, Lithium Bromide – water systems. Improvements using analyzer and rectifier. Desirable properties of combinations. Electrolux refrigerator– It‟s working.

UNIT-III

Steam jet refrigeration systems: Analysis using T-S and H-S diagrams. Quantity of motive steam required. Use of barometric and evaporative condensers. Limitations and advantages of steam jet systems.

Thermoelectric refrigeration systems: Seebeck effect, Peltier effect and Thompson effect. Analysis of the thermoelectric refrigeration systems using Peltier effect. Expression for COP. Criterion for selecting thermoelectric effects. Vortex tube refrigeration – principle and working.

UNIT-IV

Psychrometric properties of air: Psychrometric chart and psychrometric processes and combination of processes. By pass factor. SHR and Room conditioning using SHR with and without recirculation. Design and classification of Air conditioning systems, RSHF, GSHF, ERSF. Human comfort and tolerances. ASHRAE comfort charts. Effective temperature.

UNIT-V

Cryogenics: Limitations of single stage vapour compression systems applied to low temperature applications. Multistage compression and cascade systems for production of low temperature. Joule Thompson effect and coefficient. Inversion curve. Liquification of air using Linde and cloude systems. Liquification of hydrogen and helium. Application of

s in metallurgy, cryobiology and cryosurgery.

Suggested Reading:

1. Roy J. Dossat, “Principles of Refrigeration”, 5th edition, Pearson Education, 2001.
2. Jordon & Priester, “Principles of Refrigeration and Air Conditioning”, Prentice Hall, India, 1988.
3. Arora C.P., “Refrigeration and Air Conditioning”, Tata McGraw Hill, New Delhi, 1988.
4. Silberstein, Obrzut,Tomczyk, Whitman, Johnson, Refrigeration and Air Conditioning Technology,9th Edition, Cengage, January 2021.
5. G F Hundy, A. R. Trott, T C Welch, Refrigeration and Air-Conditioning, Elsevier Science, 2008.

Course Code	Course Title						Course Type
PC604ME	**PRINCIPLES OF MANAGEMENT**						**Core**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

Course Objectives:

- To enable the students to study the evolution of Management
- To study the functions and principles of management.
- To learn the application of the principles in an organization
- To enable the effective and barriers communication in the organization
- Various activates of organisation with respective different objectives
- Understand organizational structures

Course Outcomes: At the end of course, the student will be able to

1.Have clear understanding of managerial roles and evolution of management
2.To understand the planning process in the organization
3.To understand organizational structures and human resource management
4.Demonstrate the ability to directing, leadership and communicate effectively
5.To understand leadership concepts and models, values & attitudes, various approaches of time management

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	-	-	-	-	2	-	2	2	1	3	1	-	-
CO2	2	-	-	-	-	2	-	-	2	-	2	1	-	1
CO3	2	-	-	-	-	2	-	2	2	-	2	1	-	1
CO4	1	-	-	-	-	2	-	2	2	3	2	1	-	1
CO5	1	-	-	-	-	2	-	2	2	-	2	1	-	-

UNIT-I

Definition of management, science or art, manager vs entrepreneur; Types of managers managerial roles and skills; Evolution of management- scientific, human relations, system and contingency approaches

UNIT-II

Types of Business Organizations, sole proprietorship, partnership, company, public and private enterprises; Organization culture and environment; Current trends and issues in management.

Nature and purpose of Planning, types of Planning, objectives, setting objectives, policies, Strategic Management, Planning Tools and Techniques, Decision making steps & processes.

UNIT-III

Nature and purpose of Organizing, formal and informal organization, organization structure, types, line and staff authority, departmentalization, delegation of authority, centralization and decentralization, job design, human resource management, HR planning, Recruitment

selection, Training & Development, Performance Management, Career planning and Management.

UNIT-IV

Directing, individual and group behaviour, motivation, motivation theories, motivational techniques, job satisfaction, job enrichment, leadership, types & theories of leadership, effective communication.

Controlling, system and process of controlling, budgetary and non-budgetary control techniques, use of computers and IT in management control, productivity problems and management, control and performance, direct and preventive control, reporting.

UNIT-V

Behavioural aspects of entrepreneurs: Personality – determinants, attributes and models, Leadership concepts and models. Values and attitudes. Motivation aspects, change behavior. Corporate social responsibility. Time Management: Various approaches of time management, their strengths and weaknesses. The urgency addiction and time management matrix.

Suggested Reading:

1. Robins S.P. and Couiter M., Management, Prentice Hall India, 10th ed., 2009.
2. Stoner JAF, Freeman RE and Gilbert DR, Management, 6th ed., Pearson Education, 2004.
3. Tripathy PC & Reddy PN, Principles of Management, Tata McGraw Hill, 1999.
4. Harold Koontz, Cyril O'Donnell, Principles of Management an analysis of managerial functions. 1968.
5. Neharika Vohra Stephen P. Robbins, Timothy A. Judge, Organizational Behavior, 18th Editions, Pearson Education, 2022.

Course Code	Course Title							Course Type
PE621ME	**FINITE ELEMENT ANALYSIS**							**Professional Elective -II**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To understand the theory and application of the finite element method for analyzing structural systems.
- To learn Approximation theory for structural problems as the basis for finite element methods
- To learn formulations for a variety of elements in one, two, and three dimensions. Implementations of element formulations will be examined using Matlab.
- To understand modeling and analysis of structures using planar, solid, and plate elements

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Illustrate the concept of Finite Element Method and realize its limitations.
2. Construct shape functions for 1D, 2D and 3D linear and higher order elements.
3. Applying 1D, 2D and 3D elements to solve different static structural and heat transfer problems.
4. Solve 1D and 2D steady state heat transfer, and 1D eigen value and eigen vector problems.
5. Analyze time dependent heat transfer problems and review of Finite Element analyses softwares.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	-	-	2	-	-	-	-	-	-	1	1	1
CO2	2	2	-	-	2	-	-	-	-	-	-	1	1	2
CO3	3	3	2	2	3	-	-	-	-	-	-	1	2	2
CO4	3	3	2	2	3	-	-	-	-	-	-	1	2	2
CO5	2	2	-	2	3	-	-	-	-	-	-	1	2	2

UNIT-I

Introduction to Finite Element Method, solution method using FEM, discretisation, Boundary conditions, load application, types of elements comparison, Stress and Equilibrium, Boundary conditions. Strain-Displacement relations. Stress-strain relations. Types of elements used.

Convergence requirements and geometric isotropy. Local, natural and global coordinates. One Dimensional problems: Finite element modeling, coordinates and shape functions.

Potential Energy approach: Assembly of Global stiffness matrix and load vector. Finite element equations, Treatment of boundary conditions. Quadratic shape functions.

UNIT-II

Analysis of trusses and frames: Element stiffness matrix for a truss member. Analysis of plane truss with number of unknowns not exceeding two at each node. Analysis of frames with two translations and a rotational degree of freedom at each node.

Analysis of Beams: Element stiffness matrix for two nodded, two degrees of freedom per node beam element.

UNIT-III

Finite element modeling of two dimensional stress analysis with constant strain triangles and treatment of boundary conditions.

Finite element modeling of Axisymmetirc solids subjected to Axisymmetric loading with triangular elements.

UNIT-IV

Two dimensional four nodded isoprarametric elements and numerical integration.

Steady state heat transfer analysis: One dimensional analysis of a find and two dimensional analysis of thin plate. Analysis of uniform shaft subjected to torsion.

UNIT-V

Dynamic Analysis: Formulation of finite element mode, element matrices, evaluation of Eigen values and Eigen vectors for a stepped bar and a beam.

Time dependent field problems: Application to one dimensional heat flow in a rod. Finite element formation to three dimensional problems in stress analysis. Introduction to Finite Element Analysis Software.

Suggested Reading:

1. Tirupathi R. Chandraputla and Ashok, D. Belgundu" Introduction to Finite Elements in Engineering", Pearson Education, 2002, 3rd Edition.
2. Rao S.S., "The Finite Element Methods in Engineering", pergamon Press, 1989.
3. Segerlind, L.J. "Applied Finite Element Analysis", Wiley Publication, 1984.
4. Reddy J.N., "An Introduction to Finite Element Method", McGraw-Hill Company, 1984.
5. G. Ramamurty, Applied Finite Element Analysis, I. K. International Pvt Ltd, 2010.

Course Code	Course Title						Course Type
PE622ME	**ADDITIVE MANUFACTURING TECHNOLOGIES**						**Professional Elective -II**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To understand the fundamental concepts of Additive Manufacturing (AM), its advantages, limitations and classifications.
- To know the working principle, advantages, disadvantages and applications of VatPhoto Polymerization, Material Jetting, Binder Jetting, Material Extrusion powder bed 3fusion AM Technologies.
- To know the various types of STL file errors and other data formats.
- To understand features of various AM software and the concept of Topology optimization in AM.
- To understand the diversified applications of AM.

Course Outcomes: At the end of the course the student will be able to:

1. Interpret the features of Additive Manufacturing (AM) and compare it with conventional CNC Technology.
2. Illustrate the working principle, advantages, limitations and applications of various Additive Manufacturing Technologies.
3. Interpret various types of errors in STL file and other data formats used in AM and identify the role of Topology optimization in AM.
4. Analyze different types of software‟s used in 3D Printing Technology.
5. Apply the knowledge of various AM technologies for developing innovative applications.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2				1	1			1		1	1	
CO2	3	1										1	1	2
CO3	2	3		2	2								1	1
CO4	3	2	2	1	3									2
CO5	3	3	3	3	3	2	2	1	1	2	2	3	2	3

UNIT – I

Introduction: Additive Manufacturing fundamentals: Need for time compression in product development, need for Additive Manufacturing, Historical development, Fundamentals of Additive Manufacturing, AM Process Chain, Advantages and Limitations of AM, commonly used Terms, Classification of AM process, Fundamental Automated Processes: Distinction between AM and CNC, other related technologies. Role of AM in Industry 4.0.

UNIT – II

Working principle, Specifications, Materials used, Process, Applications, Advantages andDisadvantages, Case studies of the following AM Technologies:

Vat Photopolymerization AM Systems: Photopolymers, photo polymerization Stereo Lithography Apparatus (SLA), Direct Light Processing (DLP) and Continuous Direct Light Processing (CDLP). Material Jetting AM Systems: Material Jetting, Nano particle jetting and Drop-On-Demand (DOD) material jetting, Polyjet Binder Jetting AM Systems: Three dimensional Printing (3DP). Material Extrusion AM Systems: Fused Deposition Modeling (FDM).

UNIT – III

Working principle, Specifications, Materials used, Process, Applications, Advantages and Disadvantages, Case studies of the following AM Technologies:
Powder Bed Fusion AM Systems: Selective laser sintering (SLS), Selective Laser Melting (SLM) and Direct Metal Laser Sintering (DMLS), Electron Beam Melting (EBM).
Direct Energy Deposition (DED) AM Systems: Laser Engineered Net Shaping (LENS).
Sheet Lamination AM Systems: Laminated Object Manufacturing (LOM) and Ultrasonic Additive Manufacturing (UAM).

UNIT – IV

AM Data Formats: STL Format, STL File Problems, Consequence of Building Valid and Invalid. Tessellated Models, STL file Repairs: Generic Solution, Slicing Algorithms:
Design for AM: Topology optimization and Additive Manufacturing.

AM Software's: Need for AM software, Features of various AM software's like Magics, Mimics, Solid View, View Expert, 3 D Rhino, 3 D doctor, Flash Print, Object Studio, Cura, ITK Snap, 3-matic, Simplant, 3-matic, Simplant, MeshLab, Ansys for Additive Manufacturing.

UNIT –V

Additive Manufacturing Applications: AM Applications in Design, Engineering Analysis and Planning, Aerospace, Automotive, Jewelry, Coin, GIS, Arts, Architecture. Medical and Bioengineering Applications, Forensic Science, Anthropology, Visualization of Biomolecules, Electronic industry and Disaster Management.

Suggested Readings:

1. Chee Kai Chua and Kah Fai Leong, "3D Printing and Additive Manufacturing Principles and Applications" Fifth Edition, World Scientific Publications, 2017
2. Ian Gibson, David W Rosen, Brent Stucker, "Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing", Springer, Second Edition, 2010.
3. Frank W.Liou, "Rapid Prototyping & Engineering Applications", CRC Press, Taylor & Francis group, 2011.
4. RafiqNoorani, "Rapid Prototyping: Principles and Applications in Manufacturing", John Wiley & Sons, 2006.
5. C.P. Paul, A.N. Jinoop,Additive Manufacturing: Principles, technologies and Application, McGraw Hill, 2021.

Additional Reading

1 NPTEL Course on Rapid Manufacturing. https://nptel.ac.in/courses/112/104/112104265/

Course Code	Course Title						Course Type
PE623ME	**NON-CONVENTIONAL MACHINING AND FORMING METHODS**						**Professional Elective -II**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To know the various unconventional methods of machining and forming techniques.
- To understand the principles, advantages and applications of unconventional machining and forming processes.
- To know the various process parameters and their effect on machining and forming.

Course Outcomes: At the end of the course the student will be able to:

1. 1 Illustrate the basic principles of non-conventional machining techniques.
2. 2Select non-conventional machining techniques for various materials.
3. 3Illustrate principles of non-conventional forming techniques.
4. 4Select modern forming processes to various metals.
5. 5Analyze the process parameters of non-conventional machining and forming techniques.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	1	1	1	-	1	-	-	-	-	1	-	-
CO2	3	3	2	1	1	-	-	-	-	-	-	1	-	-
CO3	3	3	1	3	1	-	-	-	-	-	-	1	1	1
CO4	3	3	3	1	1	-	-	-	-	-	-	1	-	-
CO5	3	3	2	3	3	-	-	-	-	-	-	1	2	2

UNIT-I

Ultrasonic Machining (USM): Process description, abrasive slurry, Abrasive materials and their characteristics.

Functions of liquid medium in slurry. Types of Transducers, effect of process parameters, applications and limitations.

Abrasive Jet Machining (AJM): Principle of operation, process details, process variables and their effect on MRR and accuracy. Equation for MRR. Advantages, disadvantages and applications.

Water Jet Machining (WJM): Schematic diagram, equipment used, advantages and applications.

UNIT-II

Electro Discharge Machining (EDM): Process description with schematic diagram, process parameters, functions and characteristics of dielectric medium, dielectric fluids, over cut and side taper Flushing, Mechanism of metal removal, crater volume, types of power supply circuits, mathematical analysis of metal removal rate (MRR), characteristics of spark eroded surfaces, advantages, disadvantages and applications, wire electro-discharge machining principles and description.

Electro-Chemical Machining (ECM): Schematic of the process, process parameters, function and characteristics of electrolyte, chemistry of the process. Equation for specific MRR and electrode feed rate, advantages, limitations and applications.
Rotary Machining, Hot machining, high speed machining, description of each process, process parameters, advantages and applications.

UNIT-III

LASER Beam Machining (LBM): Principle of LASER Beam production, materials used, thermal analysis of the process, process parameters, equations for power density and machining rate, advantages, limitations and applications.
Plasma Arc Machining (PAM): Equipment used, process description and parameters, types of plasma arc: Transferred arc and non-transferred arc and process applications.
Electron Beam Machining (EBM): Schematic of the process, process parameters, principle of production of Electron beam, equipment used, Advantages, disadvantages and applications.
ION Etching: Process description and applications.
Hybrid Machining Processes: Principle and applications of Electro chemical discharge machining, electro chemical abrasive finishing, electro discharge abrasive grinding.

UNIT-IV

Rubber Pad Forming: Principle of the process, process details, process variants - Guerin, wheelon, Marforming and Hydro forming processes and applications.
High Energy Rate Forming (HERF): Advantages of high energy rate forming, Explosive forming: Explosive materials, standoff operation and contact operation, advantages and applications. Electro- Hydraulic Forming (EHF): Schematic of the process, description and its applications. Electro-Magnetic Forming (EMF): Process details and parameters, materials used and applications. HERF hammers.

UNIT- V

Stretch Forming: Introduction, types of stretch forming: stretch draw forming, rotary stretch forming or stretch wrapping, compression forming, radial draw forming. Stretch forming equipment and accessories, accuracy and surface finish, process variables and limitations.
Tube spinning: Introduction, methods of tube spinning, Backward spinning, Forward spinning, machines and tools used. Machine variables, speeds and feeds, effect of tube spinning on work metal properties and applications.
Hydrostatic Forming: Process principle description and applications.
Water Hammer Forming (WHF): Schematic diagram of the process, principle of operation, process variable, work materials, process limitations and applications.

Suggested Reading:

1. Pandey PC. and Shah H.S., "Modern Machining Process", Tata McGraw Hill Publishing Co. Ltd., New Delhi, 1980
2. Bhattacharya A., "New Technology", the Institution of Engineers, India, 1984.
3. Davies and Austin, "Developments in High Speed Metal Forming". The Machinery Publishing Co. Ltd., 1985
4. Mikell. P. Groover "Principles of Modern Manufacturing" Wiley India Pvt. Ltd., New Delhi, 2014.
5. Hassan Abdel-Gawad El-Hofy, Advanced Machining Processes, Nontraditional and Hybrid Machining Processes, McGraw Hill Publishing Co. Ltd.

Course Code	Course Title							Course Type
PE624ME	**NON DESTRUCTIVE TESTING**							**Professional Elective -II**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To learn the basic principles, techniques, equipment, applications and limitations of basic NDT methods.
- To learn the selection of appropriate NDT methods.
- To grasp the standards and specifications related to NDT technology.
- To know the developments and future trends in NDT.

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. After study of the course, the learner should be able to:
2. Able to understand the basic principles, techniques and equipment of NDT methods
3. Able to analyse and interpret the results from NDT TESTS
4. Able to apply the codes, standards and specifications used in NDT
5. Able to select proper NDT method for inspection of industrial productsfuture trends in NDT

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	1	-	1	-	-	-	-	-	-	1	1	1
CO2	2	2	1	2	2	2	-	1	-	-	-	1	1	1
CO3	2	3	1	3	1	2	-	1	-	-	-	1	1	1
CO4	2	3	1	2	2	2	-	1	-	-	-	1	1	1
CO5	-	-	-	-	-	-	-	-	-	-	-	-	-	-

UNIT I

Liquid Penetrant Inspection: Principles of penetrant inspection, characteristics of a penetrant, water –washable system, post-emulsification system, solvent-removable system, surface preparation and cleaning, Penetrant application, Development, Advantages limitations, and applications. Magnetic Particle Inspection: Principle, Magnetisation methods, continuous and residual methods, sensitivities, Demagnetisation, Magnetic particles, Applications, Advantages and limitations.

UNIT II

Eddy Current Testing: Principle, Lift-off factor, and edge effects, Skin effect, Inspection frequency, coil arrangements, inspection probes, types of circuit, reference pieces, phase analysis, display methods and applications.

UNIT III

Ultrasonic Testing: Generation of ultra sound, characteristics of an ultrasonic beam, sound waves at interfaces, sound attenuation, Display systems, Probe construction, type of display, Inspection techniques, Identification of defects, Immersion testing, Sensitivity & calibration. Reference standards. Surface condition, Applications.

UNIT IV

Radiography: Principle and uses of Radiography, limitations, Principle, Radiation sources, Production of X-rays, x-ray spectra, Attenuation of radiation, Radiographic equivalence, Shadow formation, enlargement and distortion, Radiographic film and paper, Xeroradiography, fluoroscopy, Exposure factors, Radiographic screens, identification markers and image quality indicators, Inspection of simple shapes, inspection of complex shapes, viewing and interpretation of radiographs, Radiation hazard, Protection against radiation, measurement of radiation received by personnel.

UNIT V

Acoustic Emission: Physical Principles, Sources of emission, instrumentation and applications.

Other NDT Techniques: Neutron radiography, Laser induced Ultrasonics, Surface analysis, Thermography.

Suggested Readings:

1. Barry Hull & Vernon John, "Non Destructive Testing", 1988.
2. HJ.Frissell (Editorial Co-Ordinator) - "Non-Destructive Evaluation and Quality Control" - ASM Hand Book - International Publication, USA, 1989.
3. Dove and Adams, "Experimental stress analysis and motion measurement", Prentice Hall of India, Delhi.
4. J Prasad, C. G. Krishnadas Nair, NON DESTRUCTIVE TEST AND EVALUATION OF MATERIALS, 2 EDITION, McGraw Hill, 2017.
5. Ravi Prakash, Non-Destructive Testing Techniques, New Age International Publishers, 2021.

Course Code	Course Title						Course Type
PE625ME	**DESIGN OF SOLAR ENERGY SYSTEMS**						**Professional Elective -II**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To develop the fundamental principle of solar radiation and it‟s measuring devises.
- To understand the concept of solar cell system and implications of solar cell system for best performance.
- To formulate solar thermal systems and also develop solar hybrid systems for different applications.

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Illustrate solar radiation and its physical function of the measuring devices.
2. Compare and contract technologies of solar cell fabrication methods.
3. Calculate the required size of solar cell systems for maximum output in peak hours.
4. Illustrate the solar thermal system for different applications.
5. Evaluate the performance of combined solar thermal and solar cell systems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	3	2	1	-	-	-	-	-	-	-	1	-	-
CO2	3	2	2	2	-	1	1	-	-	-	-	1	1	2
CO3	3	2	2	2	-	1	1	-	-	-	-	1	1	2
CO4	3	3	2	1	-	1	1	-	-	-	-	1	1	2
CO5	2	2	2	1	-	1	1	-	-	-	-	1	1	-

UNIT-I

Solar radiation: Properties of sunlight. Sun-Earth Relationships, Absorption by the atmosphere. Peak sun hours, the declination of the Sun, Determination of Solar time, Solar angle, Solar window.

Solar radiation is measuring devices: Pyrheliometers, Pyranometers. Pyrgeometer, Net radiometer, Sunshine recorder, Estimation of Average Solar radiation. Solar irradiance at surfaces

UNIT-II

Solar cells and modules: The function of solar cells from semiconductor physics. Different solar cell technologies and fabrication methods. Concepts for increasing efficiency based on loss analysis. Wavelength sensitivity. Series connection and parallel connection of solar cells to modules. Module function and characteristics. Shading of cells and modules.

UNIT-III

Solar cell systems: System components and their functions. Calculating output and dimensioning of solar cell systems. Concentrated sunlight and solar power (CSP). Properties of optical concentration systems. Solar cells in concentrated sunlight. Overview of the different components in a CSP system and their functions. Design of Photovoltaic Systems

UNIT-IV

Solar thermal: Thermodynamic description of solar collectors. Optical properties of solar collectors and technologies for fabrication. Solar thermal systems for different applications: Solar Water Heating (Active and Passive), Solar Industrial Process Heat, Solar Thermal Power Systems in India and abroad. Storage of solar generated heat. Design of Active Systems by Utilizability Methods, Design of Passive and Hybrid Heating Systems.

UNIT-V

Performance Testing of Solar Collectors:

Governing equations for evaluation of performance. Methods of testing, testing procedures, testing of liquid and air flat plate collectors. Cylindrical, parabolic concentrators. Overall performance of heating panels. Selection of materials - Absorbing heat transfer fluids.

Hybrid systems: Combinations of solar thermal and solar cell systems. Overview of different applications.

Suggested Reading:

1. Magal B.S. "Solar Power Engineering", Tata McGraw Hill Publishing Co. Ltd., 1994.
2. Sukhatme S.P.," Solar Energy", 2 Edition, Tata McGraw Hill Publishing Co. Ltd., 2nd ed, 1996.
3. Garg H.P. and Prakash J., "Solar Energy", Tata McGraw Hill Publishing Co. Ltd., 1997.
4. John A. Duffie, William A. Beckman, "Solar Engineering of Thermal Processes", 4th Edition, John Wiley & Sons Inc., 2013.
5. Mertens Konrad, “Photovoltaics: Fundamentals, Technology and Practice”, John Wiley & Sons Inc., 2014.

Course Code	Course Title						Course Type
PE626ME	**ENERGY STORAGE AND MANAGEMENT SYSTEM**						**Professional Elective -II**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Understand the storage of energy with various batteries
2. To know the battery characteristics, parameters and design for various applications
3. To know the modelling of batteries, simulation of a rechargeable batteries
4. Understand the management of batteries.
5. To know the battery testing, transport, and disposals of batteries

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	2	1	-	-	-	-	-	-	-	1	-	-
CO2	3	2	2	2	1	-	1	-	-	-	1	2	1	2
CO3	2	2	2	1	2	-	-	-	-	-	-	1	1	2
CO4	3	2	1	2	2	-	1	-	-	-	1	2	1	2
CO5	2	2	1	2	1	-	1	-	-	-	1	2	1	-

UNIT – I: ENERGY STORAGE SYSTEM

Batteries: Lead Acid Battery, Nickel based batteries, Sodium based batteries, Lithium based batteries – Li-ion & Li-poly, Metal Air Battery, Zine Chloride battery; Ultra capacitors; Flywheel Energy Storage System; Hydraulic Energy Storage System. Applications

UNIT – II: BATTERY CHARACTERISTICS & PARAMETERS

Cells and Batteries- conversion of chemical energy to electrical energy-
Battery Specifications, operating conditions, nominal and maximum characteristics; Efficiency of batteries; Electrical parameters- Heat generation- Battery design parameters, Performance criteria for Electric vehicles batteries. Vehicle propulsion factors: Power and energy requirements of batteries, Meeting battery performance criteria, setting new targets for battery performance

UNIT – III: BATTERY MODELLING

General approach to modelling batteries, simulation model of a rechargeable Li-ion battery, simulation model of a rechargeable Ni-Cd battery, Parameterization of the Ni-Cd battery model, Simulation examples.

UNIT – IV: BATTERY PACK AND BATTERY MANAGEMENT SYSTEM

Selection of battery for EVs & HEVs, Traction Battery Pack design, Requirement of Battery Monitoring, Battery State of Charge Estimation methods, Battery Cell equalization problem, thermal control, protection interface, SOC Estimation, Energy & Power estimation, Battery thermal management system, Battery Management System: Definition, Parts: Power Module, Battery, DC/DC Converter, load, communication channel, Battery Pack Safety, Battery Standards and Tests.

UNIT – V: BATTERY TESTING, DISPOSAL & RECYCLING

Chemical & structure material properties for cell safety and battery design, battery testing, limitations for transport and storage of cells and batteries, Recycling, disposal and second use of batteries. Battery Leakage: gas generation in batteries, leakage path, leakage rates. Ruptures: Mechanical stress and pressure tolerance of cells, safety vents, Explosions: Causes of battery explosions, explosive process, Thermal Runway: High discharge rates, Short circuits, charging and discharging. Environment and Human Health impact assessments of batteries, General recycling issues and drivers, methods of recycling of EV batteries.

Suggested Readings:

1. Xiaojun Tan, Andrea Vezzini, Yuqian Fan, Neeta Khare, You Xu, Liangliang Wei, Battery Management System and its Applications, WILEY,2022.
2. Valer Pop,Henk Jan Bergveld, Dmitry Danilov, Paul P.L. Regtien, Peter H.L. Notten, Battery Management Systems, Springer, 2008.

Additional Reading

1 http://nptel.ac.in/courses/108103009.

Course Code	Course Title						Course Type
PE627ME	**MACHINE LEARNING APPLICATION**						**Professional Elective -II**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- Understand the importance of data preparation & management in Machine learning applications
- Learn the basics of various statistical tools required in machine learning
- Learn to solve using regression and clustering techniques
- Learn to use concept of ANN and CNN for solving problems
- Learn to use ML and DL for mechanical applications

Course Outcomes: At the end of the course, the student will be able to:

1. Distinguish between supervised and unsupervised problem statements
2. Compare and contrast various Machine Learning and Deep Learning algorithms
3. Apply the concepts of Supervised & Unsupervised Learning to obtain the required results
4. Evaluate the importance of different algorithms used for Machine & Deep learning
5. Apply the concepts of ML and DL to the real-time data for mechanical applications and arrive at the required results.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	1	1	-	-	3	-	-	-	-	-	-	1	2	2
CO2	1	1	-	-	3	-	-	-	-	-	-	1	2	2
CO3	1	2	3	2	3	-	-	-	-	-	-	1	2	2
CO4	1	2	2	2	3	-	-	-	-	-	-	1	2	2
CO5	1	3	3	3	3	-	-	-	-	-	-	1	2	2

UNIT I

Data Preparation: Introduction, types of data, Data preparation -Data selection, Data Pre-Processing-Formatting, cleaning and sampling, Data Transformation-Scaling, Decomposition and Aggregation. Regression: Linear regression, Logistic regression, Multiple regression, Stepwise, overfitting, Regularization

UNIT II

Supervised Learning: Gradient Descent, Bias and Variance, Support Vector Machine: Hyperplanes, Kernels, Regularization, Large margin classification

UNIT III

Unsupervised learning: Clustering, k-means algorithm, Principal Component Analysis, Missing Data, choosing clusters

UNIT IV

Neural Networks: Neurons and biological motivation. Linear threshold units. Perceptrons: representational limitation and gradient descent training. Multilayer networks and

backpropagation. Hidden layers and constructing intermediate, Overfitting, learning network structure. Shallow neural networks, problems with shallow networks, importance of Deep Learning, key concepts in Deep Learning, Practical Considerations of Deep neural networks: hyper parameter tuning, initialisation, regularisation, gradient checking, optimisation algorithms, Convolutional Neural Networks, step by step procedure, Recurrent Neural Networks- step by step procedure, ALEXNET, Autoencoders.

UNIT V

Mechanical Applications of Machine Learning: ANOVA Analysis of manufacturing processes like forming, welding,

Abrasive machining, Condition Monitoring of rotary and reciprocating equipment, Condition monitoring of wind turbine, bearing fault diagnostics, Automatic car detection,

Suggested Readings:

1. Tom Mitchell, Machine Learning, McGraw Hill, Indian Edition, 2017.
2. Shai Shalev-Shwartz, Shai Ben-David, Understanding Machine Learning: From Theory To Algorithms, Third Edition, Cambridge University Press, 2015.
3. Peter Wlodarczak, Machine Learning and its Applications, 1st Edition, CRC Press, 2021.
4. John D. Kelleher, Deep Learning, The MIT Press, 2019.
5. Sebastian Raschka and Vahid Mirjalili, Python Machine Learning, Packt Publishing, 2017.

Additional Reading

1. Ian Good fellow, Yoshua Bengio, and Aaron Courville, Deep Learning, 2016.
2. Christopher M. Bishop, Pattern Recognition and Machine Learning, SPRINGER, 2009.
3. Kevin Murphy, Machine Learning: A Probabilistic Perspective, MIT Press, 2012.
4. Richard Sutton and Andrew Barto, Reinforcement Learning: An Introduction, MIT Press, 2015.

Course Code	Course Title							Course Type
PC604CS	**DEEP LEARNING**							**Professional Elective -II**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To understand complexity of Deep Learning algorithms and their limitations
- To understand modern notions in data analysis oriented computing;
- To apply Deep Learning algorithms in practical applications
- To perform experiments in Deep Learning using real-world data.

Course Outcomes: The student will be able to

1. Understand the concepts of Neural Networks, its main functions, operations and the execution pipeline
2. Implement deep learning algorithms, understand neural networks and traverse the layers of data abstraction.
3. Learn topics such as Convolutional neural networks, recurrent neural networks, training deep networks and modifications
4. Build deep learning models in PyTorch and interpret the results

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	1	2	3	1	3	-	-	-	-	-	-			-
CO2	1	3	3	1	3	-	-	-	-	-	-			-
CO3	1	2	3	1	3	-	-	-	-	-	-			-
CO4	1	3	3	3	3	-	-	-	-	-	-			-
CO5	1	-	-	-	-	-	-	-	-	-	-	-	-	-

UNIT-I

Artificial Neural Networks: Introduction, Perceptron, XOR Gate ,Perceptron Training Rule, Activation Functions.

Linear Neural Networks: Linear Regression, Implementation of Linear Regression, Softmax Regression, The Image Classification Dataset , Implementation of Softmax Regression

UNIT-II

Multilayer Perceptrons:

Multilayer Perceptrons, Implementation of Multilayer Perceptrons, Model Selection, Underfitting and Overfitting, Weight Decay, Dropout, Forward Propagation, Backward Propagation, and Computational Graphs, Numerical Stability and Initialization, Considering the Environment, Predicting House Prices on Kaggle.

Optimization Algorithms: Optimization and Deep Learning, Convexity, Gradient Descent, Stochastic Gradient Descent, Mini batch Stochastic Gradient Descent, Momentum, Adagrad, RMS Prop, Ada delta, Adam, Learning Rate Scheduling.

UNIT-III

Introduction to Convolutional Neural Networks

Introduction to CNNs, Kernel filter, Principles behind CNNs, Multiple Filters, Modern Convolutional Neural Networks

Deep Convolutional Neural Networks (AlexNet), Networks Using Blocks (VGG), Network in Network (NiN), Networks with Parallel Concatenations (GoogLeNet), Batch Normalization, Residual Networks (ResNet), Densely Connected Networks (DenseNet).

UNIT-IV

Recurrent Neural Networks: Sequence Models, Text Preprocessing, Language Models and the Dataset, Recurrent Neural Networks, Implementation of Recurrent Neural Networks from Scratch, Concise Implementation of Recurrent Neural Networks, Back propagation Through Time.

Modern Recurrent Neural Networks: Gated Recurrent Units (GRU), Long Short Term Memory (LST), Deep Recurrent Neural Networks, Bidirectional Recurrent Neural Networks, Machine Translation and the Dataset,Encoder-Decoder Architecture, Sequence to Sequence,Beam Search.

UNIT-V

Auto Encoders : Types of Auto Encoders and its applications

Generative Adversarial Networks: Generative Adversarial Network, Deep Convolutional Generative Adversarial Networks.

Suggested Readings:

1. Goodfellow, I., Bengio,Y., and Courville, A., "Deep Learning", MIT Press, 2016.
2. Aston Zhang, Zachary C. Lipton, Mu Li, and Alexander J. Smola,"Dive into Deep Learning", 2020.

Course Code	Course Title						Course Type
PE631ME	**COMPUTATIONAL FLUID FLOWS**						**Professional Elective -III**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To understand the equations of fluid flow.
- To learn Finite difference method with heat transfer equations and grid generation.
- To learn Finite volume method and staggered grid.

Course Outcomes: At the end of the course the student will be able to:

1. Establish the governing equations for different types of fluid flow systems.
2. Illustrate method of averaging of turbulent flow properties and classify second order partial differential equations.
3. Devise finite difference equations based on accuracy, type of differencing and analyse their stability.
4. Solve equations using FDM and numerical methods on discretised domain.
5. Apply Finite volume method for basic equations of heat transfer and fluid flow problems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	2	1										
CO2	3	2	2	1										
CO3	3	3	3	3	3					1				
CO4	3	3	3	3	3					1		2		1
CO5	3	3	3	3	3					1		2		1

UNIT-I

Review of basic equations of fluid dynamics: Continuity, Momentum and Energy equations-Navier-Stokes equations, Reynolds and Favre averaged N-S equations. Heat transfer conduction equations for steady and unsteady flows. Steady convection-diffusion equation.

UNIT-II

Introduction to turbulence, Mixing length model, K-ε turbulence Model.

Classification of PDEs-Elliptic, parabolic and hyperbolic equations. Initial and boundary value problems.

UNIT-III

Concepts of Finite difference methods- forward, backward and central difference. Finite difference solutions-Parabolic partial differential equations. Euler, Crank Nicholson, Implicit methods. Higher order difference methods. Errors, consistency. stability analysis- von Neumann analysis. Convergence criteria.

UNIT-IV

Numerical Methods– Jacobi, Gauss Seidel and ADI methods. 1D and 2D Elliptic partial differential equations Problems. Viscous incompressible flow, Stream function- Vorticity method. Introduction to Grid Generation- Types of grid- O,H,C.

UNIT- V

Introduction to finite volume method. Finite volume formulations for diffusion equation, convection diffusion equation. Solution algorithm for pressure velocity coupling in steady flows, Staggered grid, SIMPLE Algorithm.

Suggested Reading

1. Muralidhar K, Sundararjan T, Computational Fluid Flow and Heat transfer, Narosa Publishing House, 2003.
2. Chung, T J, Computational Fluid Dynamics, Cambridge University Press, 2002.
3. Patankar, S V, Numerical Heat transfer and Fluid flow, Hemisphere Publishing Company, New York, 1980.
4. John D Anderson, Computational Fluid Dynamics, Mc Graw Hill, Inc., 1995.
5. Pradip Niyogi, Chakrabartty S K, Laha M K, Introduction to Computational Fluid Dynamics, Pearson Education, 2005.

Course Code	Course Title						Course Type
PE632ME	**CRYOGENIC TECHNOLOGY**						**Professional Elective -III**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To provide the knowledge of evolution of low temperature science.
- To learn the technology of refrigeration and gas liquefaction.
- To know various equipment used for cryogenic systems.
- To understand the methods of separation and purification systems.
- To familiarize the cryogenic instruments.

Course Outcomes:

1. Identify the cryogenic application and understand material properties.
2. Estimate and analyze the refrigeration and liquefaction for minimum work.
3. Design the various heat exchangers and other components.
4. Describe the methods of separation and purification.
5. Explain about cryogenic instrumentation and Safety aspects.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	2									2	3	
CO2	3	3	2									2	3	
CO3	3	3	2									2	3	
CO4	3	3	2									2	3	
CO5	3	3	2									2	3	

UNIT–I

Introduction to Cryogenics: Historical development, Applications of cryogenics (Space Technology, Food Processing, Super Conductivity, Electrical Power, Cryobiology, Medicine, Cryo-metallurgy), nuclear, chemical and rocket propulsions.

Properties of Engineering Materials: Solids (Mechanical, Thermal, Electrical and Magnetic properties), Properties of Cryogenic fluids.

UNIT-II

Refrigeration and Liquefaction: Refrigeration and liquefaction principles, Joule-Thomson expansion, Isentropic expansion, Linde- Hampson cycle, Claude cycle and Cascade systems. Magnetic cooling, Striling cycle, Cryocoolers, Philip refrigerators, Solvay refrigerator, Gifford – McMahon refrigerator, pulse tube refrigerator.

UNIT-III

Cryogenic Equipments: Heat exchangers, Compressors, Expanders, Effect of various parameters in performance and system optimization. Various insulations and storage equipment for cryogenic fluids. Industrial storage and Transfer of cryogenic fluids.

UNIT-IV

Separation and Purification Systems: Ideal separation of gases, Characteristics of mixtures, Temperature-Composition diagrams, Enthalpy-Concentration diagrams. Principles of gas separation, Air separation systems, Hydrogen separation systems, Helium separation systems. Gas purification methods.

UNIT-V

Cryogenic Instrumentation and Safety: Properties characterizing cryogenic instrumentation. Temperature measurements, Pressure, flow-rate, Liquid-level. Safety in cryogenic fluid handling, Precautions and Protection measures.

Suggested Reading:

1. Randal F. Barron, Cryogenic Systems, Oxford University Press, New York, 1999.
2. T.M Flynn, Cryogenic Engineering, Maxwell Dekker, 1997.
3. Scoot, Cryogenic Engineering, Van Nostrand Co. Inc. 1985.
4. Mamata Mukhopadhyay, Fundamentals of Cryogenic Engineering, PHI Learning Private Limited, 2010.
5. A.Arkherov, I.Marfenina, Ye.Mikulin,Theory and design of cryogenic systems,Imported Pubn, 1981.

e-Resources:

1. http://nptel.ac.in/

Course Code	Course Title						Course Type
PE633ME	**MACHINE TOOL ENGINEERING AND DESIGN**						**Professional Elective -III**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To learn and applications of the basics and working principles of different types of machine tools
- To grasp the knowledge of critical functional and operational requirements of different types of machine tools
- To learn the knowledge of design of different types of machine tools to meet varied functional and operational requirements.

Course Outcomes: Student will be able to

1. Understand the basic working principles of different machine tools with kinematic mechanisms.
2. Distinguish the functional and operational requirements of different machine tools
3. Design speed and feed gear boxes for a particular configuration.
4. Design machine tool structures for strength and rigidity
5. Understand various controls used in machine tools

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	1	1	2			1	2		2	1	2	1
CO2	3	3	2	2	2	1	1	1	2	1	2	1	3	1
CO3	2	3	3	2	2				1	2	2	2	3	1
CO4	2	3	3	2	1		1		1	2	2	3	2	1
CO5	2	2	2	1	3	1	1		2	1	3	2	2	2

UNIT I

Basic features: Classification of machine tools-Basic features of construction and fundamental kinematic mechanisms of general purpose, special purpose machine tools, transfer machines, Automatic and N.C. machines. Mechanisms used for converting rotary to linear motion: Mechanisms for intermittent motion.

UNIT II

Kinematics, Drives of Machine tools: Selection of range of speeds and feeds. Layout in G.P., A.P. and Logarithmic progression, standardization of speeds and feeds. Productivity loss. Selection of highest and lowest speeds, range ratio. Design of ray diagram" and structural diagrams for machine tool gear boxes. Sliding, clustered and clutched drives, Rupport drive.

UNIT III

Feed gear boxes: Norton and Meander drives pre-selection of speed, stepped and stepless regulation. Strength, rigidity and design analysis: Analysis of beds, frames, columns. Materials for structures. Methods to improve the rigidity of structures. Types of Guide ways-overall compliance of machine tool. Thermal effects-functional accuracy of machine tool.

UNIT IV

Spindle units: Spindle units of lathe, drilling, milling and grinding machines, materials for spindles. Spindle design. Effect of clearance on the rigidity of spindle. Hydrodynamic, hydrostatic, rolling bearings. Selection of bearings.

UNIT V

Hydraulic controls: Various controls used in machine tools. Hydraulic and pneumatic systems used in machine tools-positive displacement pumps - properties of fluids — relief valves, check valves, flow control valves, multi-position valves, filters, accumulators. Hydraulic circuit for surface grinding machine, hydro-copying system.

Suggested Reading:

1. Sen G.S., & Battacharya, "Principles of Machine Tools", New Central Book Agency, Calcutta, 1986.
2. Basu S.K., "Design of Machine Tools", Allied Publishers, 1980.
3. Russe W. Henke, "Introduction to Fluid Power Circuits and Systems", Addison Wesley, 1970.
4. N. K. Mehta, Machine Tool Design, Tata McGraw Hill Education Pte. Limited, 2012.
5. CMTI - Machine Tool Design Handbook, Kojo Press, 2024.

Course Code	Course Title							Course Type
PE634ME	**TOTAL QUALITY MANAGEMENT**							**Professional Elective -III**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- Develop quality environment to the organization.
- Describe the TQM approach for manufacturing/service organization in length.
- Categorise various Quality terms like Tolerance and Variability, PDCA cycle,Crosby‘s10 points and Deming‘s14Points.
- Identify international and national Quality awards

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Understand the significance of quality in manufacturing
2. Rectify the deviations in quality in manufacturing
3. Practice the quality standards in the organization

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	-	-	3	2	2	-	2	2	2	1	2	-	2
CO2	2	-	-	3	2	2	-	2	2	2	1	2	-	2
CO3	2	-	-	3	2	2	-	2	2	2	1	2	-	2
CO4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO5	-	-	-	-	-	-	-	-	-	-	-	-	-	-

UNIT-I

Evolution of Quality-Historical Perspective, Basic Concepts of Quality, Vision, Mission and Objectives of an Organization, Corporate Structure in an Organization and Role of Quality. Quality Planning, Quality by Design, Quality Costs and Cost of Failure, Waste Control, How Quality Benefits Business.

UNIT-II

Quality and Competitiveness in Business, Zero Defects and Continuous Improvement, Role of Leadership and Commitment in Quality Deployment, Team Building, Motivation and Rewards, Total Employee Empowerment, Quality Functions-Measurement, Inspection, Testing, Calibration and Assurance.

UNIT-III

Design Control and Conformity, Tolerance and Variability, PDCA Cycle, Juran Trilogy, Crosby‘s
10 points and Deming‘s14Points Customers Requirements, Customer-Supplier and Chain Links, Establishing Customer Focus-Customer, Satisfaction, Measurement and Customer Retention.

UNIT-IV

Product Liability, Total Quality Concepts and CWQC, Difference in Western And Japanese

Approach of TQM, Basic Philosophy and Fundamental Models of TQM, Total Quality and Ethics.

UNIT-V

Internal Politics and Total Quality Management, Quality Culture, Education and Training Implementing Total Quality Management- An Integrated System Approach Total Preventive Maintenance. Self-Assessment, International/National Quality Awards: Malcolm Baldridge Award, Deming Prize, European Award, Rajeev Gandhi Award, CII Exim Award, Jamna Lal Bajaj Award, Golden Peacock Award.

Suggested Reading:

1. Total Quality Management by N.V.R.Naidu, G. Rajendra New Age International, First Edition, Jan2006.
2. Total Quality Management by R.S Naagarazan, New Age international,3e,2015.
3. Quality Control & Application by B. L.Hanson &P. M. Ghare, Prentice Hall of India,2004.
4. Total Quality Management by V.S Bagad Technical Publications, First Edition, Jan2008.
5. Total Quality Management by S. Rajaram Dreamtech Press, First Edition, Jan2008.

Course Code	Course Title							Course Type
PE635ME	**FATIGUE CREEP AND FRACTURE**							**Professional Elective -III**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives

- Learn the concepts of fatigue design and testing.
- Understand the factors affecting fatigue strength.
- Conceptualize the theory of brittle fracture and understand the modes of fracture and its measurement.
- Learn the mechanism of creep and its importance in design.

Course Outcomes: At the end of the course the student will be able to:

1. Enumerate the design philosophy and recognize formulate fatigue design.
2. Illustrate the factors affecting fatigue and methods to improve fatigue strength.
3. Evaluate ductile and brittle fracture.
4. Predict the stress field at the crack tip.
5. Calculate and measure creep deformation.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	2	2	1							1	1	1
CO2	3	3	2	2	1							1	1	1
CO3	3	3	2	2	1							1	1	1
CO4	3	3	2	2	1							1	1	1
CO5	3	3	2	2	1							1	1	1

UNIT I:

Design philosophy: Infinite life, Safe life, Fail safe and Damage tolerant design concepts.
Fatigue Design: Cyclic stress and stress reversals, Fatigue and progressive fracture, Endurance limit, Fatigue Tests: Cantilever and Beam type of Fatigue Tests, Axial Fatigue Tests. Influence of mean stress on fatigue: Gerber, Goodman and Soderberg‟s criteria. Effect of compressive cyclic stress on fatigue. Fatigue design formula for axial, bending, torsional and combined loading.

UNIT II:

Fatigue controlling factors: Effect of frequency, Temperature, size, form, stress concentration factors, Notch, sensitivity & surface conditions, residual stresses. Improvement of fatigue strength by chemical/metallurgical processes such as nitriding, flame hardening, case carburizing. Fatigue strength enhancement by mechanical work : cold rolling, peening, shot peening.

UNIT III:

Effect of environment: Corrosion Fatigue, Concept of cumulative fatigue damage Fracture Mechanics: Ductile and brittle fracture Theoretical cohesive strength of metals, Griffith Theory of brittle Fracture, Oruron‟s modification to Griffith Theory.

UNIT IV:

Modes of Fracture: Mode-I, -II and -III, fatigue crack growth, Behaviour of metals, Linear Elastic Fracture Mechanics (LEFM), Stress Intensity Factor(SIF), Stress field near the crack tip, Critical SIF and Fracture Toughness, Experimental determination of fracture toughness KIC , COD gauges and standard ASTM Tests.

Strain Energy Release Rates (SERR), Elasto-Plastic Fracture Mechanics (EPFM), Plastic zone size and its evaluation, J-Integral Method.

UNIT V:

Creep Analysis: Definition, Constant stress and constant, strain creep tests. Uniaxial creep tests: Baily‟s Power Law, Creep relaxation: strain hardening and time hardening creep relaxation. Introduction to Creep bending and deflection of simple problems.

Suggested Reading

1. George E. Dieter, Mechanical Metallurgy, - Mc Graw Hill, NY,1988
2. Joseph Marin, Mechanical Behaviour of Engg. Materials, - Prentice Hall of India, 1966
3. Stephens, R.I. and Fuchs, H.O., Metal Fatigue in Engg. ,- Wiley, NY 2001.
4. Finnie, I. and Heller, W.R., Creep of Engg. Materials, - Mc Graw Hill Book Co., 1959
5. Prasant Kumar, Elements of Fracture Mechanics, McGraw Hill Education, 2017.

Course Code	Course Title							Course Type
PE636ME	**ADVANCED PROPULSION AND SPACE SCIENCE**							**Professional Elective -III**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To learn about gas dynamic concepts of rocket propulsion system
- To learn rocket engine system.
- To learn celestial sphere and its parameters
- learn about Satellites & Remote Sensing

Course Outcomes: Student will be able to

1. Classify different rocket propulsion systems and understand the concept of gas dynamics
2. Understand the working principle of rocket engine system
3. Understand celestial sphere and its parameters

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	3	1	1	-	1	-	-	-	-	1	1	1
CO2	3	3	3	1	1	-	1	-	-	-	-	1	1	1
CO3	3	3	2	1	1	-	1	-	-	-	-	1	1	1
CO4	3	3	2	2	2	-	1	-	1	-	-	1	2	1
CO5	3	3	2	2	3	-	1	-	2	-	-	1	2	1

UNIT I

Advanced Gas Dynamics: Normal shock waves, pitot tubes, moving shock waves, oblique shock waves, reflected shock waves, conical shock waves, hypersonic flow, Newtonian theory, high temperature flows, low density flows.

UNIT II

Advanced Propulsion: Rocket engines - Operation and performance of rocket engines, design and operating parameters - total impulse, thrust, energy and efficiencies, Typical performance values, overview of monopropellant, bipropellant liquid, solid and hybrid rocket propulsion systems, combined cycle propulsion, Electric / Ion propulsion.

UNIT III

Rocket Technology: Flight mechanics, application thrust profiles. Acceleration -staging of rockets, feed systems, injectors and expansion nozzles, typical nozzle designs (cone, bell, plug).Rocket heat transfer and ablative cooling. Testing and Instrumentation. Nuclear thermal rockets, pulsed detonation engines, Solar sails.

UNIT IV

Celestial Sphere: Spherical trigonometry, celestial coordinate systems, Astronomical triangle, Time-Sidereal, apparent and mean solar time. Equation of Time.

Two Body Problem: Formulation, relative motion and solution, Kepler's equation, motions of rockets and artificial satellites, transfer orbits, minimum energy interplanetary transfer orbits, use of parking orbits, Perturbations of artificial satellites due to atmospheric drag and flattening of earth.

UNIT V

Nuclear Processes in the Sun, Solar wind, interaction of solar Wind and Earth's magnetic field, Van Allen radiation belts.

Satellites & Remote Sensing: Orbits, earth segment, space segment, earth station, satellite subsystems, working details of communication and navigational satellites - components, operation and maintenance, meteorological satellites. Principles of remote sensing

Suggested Reading:

1. Shapiro, "The dynamics and thermodynamics of compressible flow", 1953.
2. Thomas, D. Daman, "Introduction to space: The Science of space flight", Orbit book Co., Rd ed., Malabar, FL, 2001.
3. K.D. Abhyankar, "Astrophysics of the solar systems", University Press (India) Ltd., 1999.
4. Timothy Pratt and Charles, W. Bostian, "Satellite Communications", John Wiley, 1988.
5. Martin Tajmar, Advanced Space Propulsion Systems, Springer Verlag GmbH, 2002.

Course Code	Course Title						Course Type
PE637ME	**MECHATRONICS SYSTEMS**						**Professional Elective -III**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

Course Objectives

- Learn the architecture of mechatronic systems
- Introduce concept of sensors & actuators to measure & control various physical quantities like volume, pressure, temperature
- Learn to design simple control systems
- Learn PLC programming to build simple control systems

Course Outcomes: At the end of the course the student will be able to:

1. Illustrate the architecture of mechatronic systems.
2. Design some simple measurement systems using different sensors.
3. Demonstrated ability to design basic control systems using different actuators.
4. Execute PLC programs for industrial Applications.
5. Demonstrate an understanding of analogue and digital interfacing.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	1	2	1	-	-	-	-	-	-	1	-	-
CO2	3	3	1	2	2	-	-	-	-	-	-	1	1	-
CO3	3	3	2	2	2	-	-	-	-	-	-	1	1	-
CO4	3	2	2	2	2	-	-	-	-	-	-	1	1	1
CO5	3	2	1	1	1	-	-	-	-	-	-	1	1	1

UNIT 1:

Introduction: Definition of Mechatronics, Mechatronics in manufacturing, Products, and design. Comparison between Traditional and Mechatronics approach.

UNIT II:

Review of fundamentals of electronics. Data conversion devices, sensors, microsensors, transducers, signal processing devices, relays, contactors and timers. Microprocessors controllers and PLCs.

UNIT III:

Drives: stepper motors, servo drives. Ball screws, linear motion bearings, cams, systems controlled by camshafts, electronic cams, indexing mechanisms, tool magazines, transfer systems.

UNIT IV:

Hydraulic systems: flow, pressure and direction control valves, actuators, and supporting elements, hydraulic power packs, pumps. Design of hydraulic circuits. Pneumatics: production, distribution and conditioning of compressed air, system components and graphic representations, design of systems. Description

UNIT V:
Description of PID controllers. CNC machines and part programming. Industrial Robotics.

Suggested Readings:

1. David Alciatoare, Michael Histand, "Introduction to Mechatronics and Measurement Systems",McGraw Hill, 2002.

2. Boltan, W., "Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering", Longman, Singapore, 1999.
3. Devdas Shetty, Richard Klok "Mechatronic system design", 2nd edition, Cengage Learning, 2010.
4. Herbert Taub & Donald Schilling : Digital Integrated Electronics, McGraw Hill International Edition, 1977.
5. Krishna Kant; Computer Based Industrial Control ; Prentice Hall of India Pvt. Ltd. 1999.

Additional Resources

1. HMT ltd. Mechatronics, Tata Mcgraw-Hill, New Delhi, 1988.
2. G.W. Kurtz, J.K. Schueller, P.W. Claar . II, Machine design for mobile and industrial applications, SAE, 1994.
3. T.O. Boucher, Computer Automation in Manufacturing - an Introduction, Chappman and Hall, 1996.
4. Haxkworth, "Programmable Logic Controllers-Programming Methods and its Applications", Pearson India Ltd., 2011.

Course Code	Course Title						Course Type
PE638ME	**VIRTUAL REALITY AND AUGMENTED REALITY**						**Professional Elective -III**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- Learn the basics of VR and AR
- Learn how to build objects in Unity IDE
- Learn to build controllers in Unity IDE
- Learn to build environment in Unity IDE
- Learn to generate animated walk in Unity IDE

Course Outcomes: At the end of the course, the student will be able to:

1. Differentiate Virtual and Augmented Realities
2. Understand Virtual reality concepts
3. Develop VR applications using Unity3D
4. Move around the 3D world
5. Run Unity 3D application in VR on a smart phone

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	1							2	1	2	2	1
CO2	3	2								1	1	2	2	1
CO3		1	3	2	3					1	1	3	3	2
CO4			2	2	2					1		2	2	2
CO5			3	2	3					1		2	3	2

UNIT-I

Introduction to Virtual Reality: Virtual Reality – Types – Virtual Reality Vs Augmented Reality – Applications – Technical skills required

UNIT-II

Building Simple Scenes: Introduction to Unity IDE – Objects and Scale – Creating a simple diorama – VR Device integration

UNIT-III

Gaze Based Control: First person Controller – Third person controller – Navigation in VR application – World space User Interface

UNIT-IV

Physics & Environment: Physics component – physics materials – Raycast – particle effects

UNIT -V

Walk-Throughs: Assembling scenes – Adding photos – Animated walkthrough – optimizing for performance – Using all 360 degrees

Suggested Readings:

1. Tony Parisi, Learning Virtual Reality, O'Reilly Media, 2016
2. Jason Jerald, The VR Book – Human Centered Design for Virtual Reality, Morgan & Claypool, 2015.
3. John Williamson, Charles Palmer, Virtual Reality Blueprints: Create compelling VR experiences for mobile and desktop, Packt Publishing, 2018.
4. Dieter Schmalstieg, Tobias Hollerer, AUGMENTED REALITY: PRINCIPLES AND PRACTICE, First Edition, Pearson Education India, 2016.
5. Jesse Glover, Complete Virtual Reality and Augmented Reality Development with Unity, Packt Publishing, 2019.

Course Code	Course Title							Course Type
OE601CE	**DISASTER MANAGEMENT**							**Open Elective -I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To introduce basic conceptual understanding of natural & man-made hazards and different contextual aspects.
- To develop the knowledge and understanding of the International and national strategy for disaster reduction (UN-ISDR)
- To ensure skills and abilities to analyze potential effects of disasters and of the strategies and methods to deliver public health response to avert these effects.
- To promote the use of science and technology for implementing the disaster risk reduction (DRR) plans and policies.

Course Outcomes:

1. Aptitude to link hazards, risk, vulnerability, differential impacts and capacity building to the life and property loss during disasters and its impacts on the society and sustainability.
2. Ability to understand various aspects of natural and man-made hazards and emerging trends
3. Acquaintance with different steps involved in disaster risk reduction (DRR) and international initiatives for prevention, mitigation and preparedness.
4. Knack to appreciate the national policy and role of individuals, communities, and government organizations in disaster management.
5. Capacity to identifying current technological constraints and hazard specific solutions, particularly construction codes etc.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1		2								1	1	
CO2	3	1		2								1	1	
CO3	3	1		2								1	1	
CO4	3	1		2								1	1	
CO5	3	1		2								1	1	

UNITI: INTRODUCTION TO DISASTER

- Understanding the Concepts, Definitions and Terminologies used in the field of Disaster Management (i.e. Hazard, Risk, Vulnerability, Resilience, and Capacity Building).
- Differential impacts of Disasters in terms of Gender, Age, Social Status, Location, Prosperity, Disabilities.
- Disaster- Development Nexus.

UNIT II: TYPES of HAZARDS AND EMRGING TRENDS

- Classification, Causes, Consequences and Controls of
  - Geophysical hazards-Earthquakes, Landslides, Tsunami
  - Weather related hazards- Meteorological (Cyclones, Storm-surge and Lighting) Hydrological (Floods, Droughts, Avalanches)

- Climatological (Wildfire, Cold & Heat Waves)
    - Biological hazards-Epidemic & Pandemics,
    - Technological hazards-Chemical, Industrial, Nuclear
    - Man-made hazards-Structural Failure, Fire, Transportation accidents, Terrorism and Wars
- Emerging Disasters- Urban Areas, Climate Change.
- Regional and Global Trends-loss of life & Property in various hazards

UNIT III: DISASTER MANAGEMENT CYCLE AND INTERNATIONAL FRAMEWORK

- Disaster Management Cycle
- Pre-Disaster – Risk Assessment and Analysis, Risk Mapping, zonation and Microzonation, Prevention and Mitigation of Disasters, Early Warning System; Preparedness, Capacity Development; Awareness
- During Disaster – Evacuation – Disaster Communication – Search and Rescue– Emergency Operation Centre – Incident Command System – Relief and Rehabilitation –
- Post-disaster – Damage and Needs Assessment, Restoration of Critical Infrastructure – Early Recovery – Reconstruction and Redevelopment
- Paradigm Shift in Disaster Management: International Decade for Natural Disaster Reduction; Yokohama Strategy; Hyogo Framework of Action

UNIT IV: DISASTER RISK MANAGEMENT IN INDIA

- Disaster Profile of India – Mega Disasters of India and Lessons Learnt
- Disaster Management Act 2005 – Institutional and Financial Mechanism
- National Policy on Disaster Management,
- National Guidelines and Plans on Disaster Management;
- Role of Government (local, state and national),Non-Government and Inter-governmental Agencies

UNIT V: TECHNOLOGICAL APPROACHES TO DISASTER RISK REDUCTION

- Geo-informatics in Disaster Management (RS, GIS, GPS and RS)
- Disaster Communication System (Early Warning and Its Dissemination)
- Land Use Planning and Development Regulations
- Disaster Safe Designs and Constructions
- Structural and Non Structural Mitigation of Disasters
- Science &Technology Institutions for Disaster Management in India

Suggested Readings:

1. Coppola D P, 2007. Introduction to International Disaster Management, Elsevier Science (B/H), London.
2. Manual on natural disaster management in India, M C Gupta, NIDM, New Delhi
3. An overview on natural & man-made disasters and their reduction, R K Bhandani, CSIR, New Delhi
4. World Disasters Report, 2009. International Federation of Red Cross and Red Crescent,Switzerland
5. Disasters in India Studies of grim reality, AnuKapur& others, 2005, 283 pages, Rawat Publishers, Jaipur
6. 10 Disaster Management Act 2005, Publisher by Govt. of India
7. Publications of National Disaster Management Authority (NDMA) on Various Templatesand Guidelines for Disaster Management
8. National Disaster Management Policy, 2009, GoI

Course Code	Course Title						Course Type
OE602CE	**ROAD SAFETY ENGINEERING**						**Open Elective -I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives: The course is taught with the objectives of enabling the student to:

- To introduce the fundamentals of road safety and road safety audit
- To get familiarized with various road safety techniques, measures and their applications
- To be able to understand and evaluate various traffic control devices
- Familiarize with traffic management techniques
- To examine and analyze the incident management process

Course Outcomes: On completionofthis course, thestudentwill beable to:

1. Analyze Accident data
2. Plan and design of road safety improvement programs
3. Apply the principles of road safety in urban transport
4. Apply traffic management techniques
5. Able to plan effective incident management program

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1		2								1	1	
CO2	3	1		2								1	1	
CO3	3	1		2								1	1	
CO4	3	1		2								1	1	
CO5	3	1		2								1	1	

UNIT-I

Road accidents: Causes, scientific investigations and data collection, analysis of individual accidents to arrive at real causes, statistical methods of analysis of accident data, Basic concepts of road accident statistics, safety performance function: The empirical Bayes method identification of hazards road location. Application of computer analysis of accident data.

UNIT-II

Safety in Road Design: Operating the road network for safety, highway operation and counter measures, road safety audit, principles-procedures and practice, code of good practice and checklists, vehicle design factors & driver characteristics influencing road safety.

UNIT-III

Road Signs and Traffic Signals: Classification, Location of signs, measures of sign effectiveness, Types of visual perception, sign regulations, sign visibility, sign variables, Text versus symbols, Road marking: Role of road marking, classification, visibility. Traffic signals: Need, Signal face illumination and location of signals, factors affecting signal design,

pedestrian's safety, fixed and vehicle actuated signals. Design of signals, area traffic control, Delineators, traffic impact attenuators, road side rest areas, safety barriers, traffic aid posts.

UNIT-IV

Traffic Management Techniques: Integrated safety improvement and traffic calming schemes, speed and load limit, traffic lights, safety cameras, tests on driver and vehicles, pedestrian safety issues, parking, parking enforcement and its influence on accidents, travel demand management, methods of traffic management measures: restriction of turning movements, One way streets, tidal flow operation methods, exclusive bus lanes and closing side-streets; latest tools and techniques used for road safety; legislation, enforcement, education and propaganda.

UNIT-V

Incident Management: Introduction, characteristics of traffic incidents types of incidents, impacts, incident management process, incident traffic management; application of ITS: Motorist information, equipment used; planning effective incident management program, best practice in incident management programs. National importance of survival of transpiration systems during and after all natural disasters especially cyclones, earthquakes, floods etc and manmade disasters like sabotage, terrorism etc.

Suggested Reading:

1. Khanna, S.K., Justo, C.E.G and Veeraragavan, A, 'Highway Engineering', Revised 10th Edition, Nem Chand & Bros, 2017.
2. KadiyaliL.R, Lal, N.B., 'Principles and Practices of Highway Engineering' Khanna Publishers, 7e, 2017.
3. IRC 93 ' Guidelines for the design of road traffic signals' IRC, New Delhi.
4. C. Jotinkhisty and B. Kent Lall, Transportation Engineering – An Introduction, 3rd Edition, Pearson publications, 2017.
5. Rune Elvik, Alena Hoye, TrulsVaa, Michael Sorenson, Handbook of Road Safety measures, second Edition, Emerald Publishing, 2009.

Course Code	Course Title						Course Type
OE601ME	**3D PRINTING TECHNOLOGY**						**Open Elective-I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To understand the fundamental concepts of 3D Printing, its advantages and limitations.
- To know the working principle, advantages, disadvantages and applications of liquid, solid and Powder based 3D Printing Technologies.
- To know the various types of STL file errors and other data formats used in 3D Printing Technology.
- To know the features of various 3D Printing software's.
- To know diversified applications of 3D Printing Technologies.

Course Outcomes: At the end of the course the student will be able to:

1. Interpret the features of 3D Printing and compare it with conventional methods.
2. Illustrate the working principle of liquid, solid and powder based 3D Printing Technologies.
3. Identify various types of errors in STL file and other data formats used in 3D Printing Technology.
4. Select suitable software used in 3D Printing Technology.
5. Apply the knowledge of various 3D Printing technologies for developing innovative applications.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2				1	1			1		1	1	
CO2	3	1										1	1	2
CO3	2	3		2	2								1	1
CO4	3	2	2	1	3									2
CO5	3	3	3	3	3	2	2	1	1	2	2	3	2	3

UNIT-I

Introduction: Prototyping fundamentals: Need for time compression in product development, Historical development, Fundamentals of 3D Printing, 3D Printing Process Chain, Advantages and Limitations of 3D Printing, 3D Printing wheel, Commonly used Terms, Classification of 3D printing processes, Fundamental Automated Processes: Distinction between 3D Printing and Conventional Machining Processes.

UNIT-II

Liquid-based 3D Printing Systems: Stereo Lithography Apparatus (SLA): Models and specifications, Process, working principle, photopolymers, photo polymerization, Layering technology, laser and laser scanning, Applications, Advantages and Disadvantages, Case studies. Polyjet: Models and specifications, Process, working principle, Applications, Advantages and Disadvantages, Case studies Solid-based 3D Printing System: Laminated

Object Manufacturing (LOM): Models and specifications, Process, working principle, Applications, Advantages and Disadvantages, Case studies. Fused Deposition Modeling (FDM): Models and specifications, Process, working principle, Applications, Advantages and Disadvantages, Case studies.

UNIT-III

Powder Based 3D Printing Systems: Working principle, Specifications, Materials used, Process, Applications, Advantages and Disadvantages, Case studies of the following 3D Printing Technologies like Selective laser sintering (SLS), Selective Laser Melting (SLM) and Direct Metal Laser Sintering (DMLS), Laser Engineered Net Shaping (LENS), Electron Beam Melting (EBM),

UNIT-IV

3D Printing Data Formats & Software: STL Format, STL File Problems, Consequence of Building Valid and Invalid Tessellated Models, STL file Repairs: Generic Solution, Other Translators, Newly Proposed Formats. 3D Printing Software's Features: Magics, Mimics, Solid View, View Expert, 3 D Rhino, 3 D doctor, Flash Print, Object Studio, Cura, ITK Snap, 3-matic, Simplant, 3-matic, Simplant, MeshLab, Ansys for Additive Manufacturing.

UNIT-V

Applications of 3D Printing : Application in Design, Application in Engineering, Analysis and Planning, Aerospace Industry, Automotive Industry, Electronic Industry, Jewellery Industry, Coin Industry, GIS application, Arts and Architecture. RP Medical and Bioengineering Applications: Planning and simulation of complex surgery, Customized Implants & Prosthesis, Design and Production of Medical Devices, Forensic Science and Anthropology, Visualization of Biomolecules. Biopolymers, Packaging, Disaster Management, Entertainment and Sports industry.

Suggested Readings:

1. Chee Kai Chua and Kah Fai Leong, "3D Printing and Additive Manufacturing Principles and Applications" Fifth Edition, World scientific
2. Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing- Ian Gibson, David W Rosen, Brent Stucker, Springer, Second Edition, 2010.
3. Rapid Prototyping & Engineering Applications – Frank W.Liou, CRC Press, Taylor & Francis Group, 2011.
4. Rafiq Noorani, Rapid Prototyping: Principles and Applications in Manufacturing, John Wiley & Sons, 2006.
5. NPTEL Course on Rapid Manufacturing. https://nptel.ac.in/courses/112/104/112104265/

Course Code	Course Title							Course Type
OE602ME	**FINITE ELEMENT METHOD**							**Open Elective-I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To understand the theory and application of the finite element method for analyzing structural systems.
- To learn Approximation theory for structural problems as the basis for finite element methods.
- To learn formulations for a variety of elements in one, two, and three dimensions. Implementations of element formulations will be examined using Matlab.
- To understand modeling and analysis of structures using planar, solid, and plate elements

Course Outcomes: Upon successful completion of this course, the student will be able to:

1. Demonstrate a basic understanding of the concepts, mathematical formulation and numerical implementation.
2. Demonstrate the ability to invoke appropriate assumptions, select proper elements and develop FEA models that adequately and efficiently represent physical systems.
3. Underlying the FEA as applied to solid mechanics.
4. Solve 2D vector variable problems and analyze higher order elements and its applications.
5. Create his/her own FEA computer programs using Matlab to solve simple engineering problems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1		2								1	1	
CO2	3	1		2								1	1	
CO3	3	1		2								1	1	
CO4	3	1		2								1	1	
CO5	3	1		2								1	1	

UNIT I: Introduction

Historical Background – Mathematical Modeling of field problems in Engineering – Governing Equations – Discrete and continuous models – Boundary, Initial and Eigen Value problems– Weighted Residual Methods – Variational Formulation of Boundary Value Problems – Ritz Technique – Basic concepts of the Finite Element Method.

UNIT II: One-Dimensional Problems

One Dimensional Second Order Equations – Discretization – Element types- Linear and Higher order Elements – Derivation of Shape functions and Stiffness matrices and force vectors- Assembly of Matrices – Solution of problems from solid mechanics and heat transfer. Longitudinal vibration frequencies and mode shapes.

UNIT III: Two Dimensional Scalar Variable Problems

Second Order 2D Equations involving Scalar Variable Functions – Variational formulation – Finite Element formulation – Triangular elements – Shape functions and element matrices and vectors. Application to Field Problems – Thermal problems – Torsion of Non circular shafts –Quadrilateral elements – Higher Order Elements.

UNIT IV: Two Dimensional Vector Variable Problems

Equations of elasticity – Plane stress, plane strain and axisymmetric problems – Body forces and temperature effects – Stress calculations – Plate and shell elements.

UNIT V: Isoparametric Formulation

Natural co-ordinate systems – Isoparametric elements – Shape functions for iso parametric elements – One and two dimensions – Serendipity elements – Numerical integration and application to plane stress problems – Matrix solution techniques – Solutions Techniques to Dynamic problems – Introduction to Analysis Software.

Suggested Reading:

1. Tirupathi R. Chandraputla and Ashok, D. Belgundu" Introduction to Finite Elements in Engineering", Pearson Education, 2002, 3rd Edition.
2. Rao S.S., "The Finite Element Methods in Engineering", pergamon Press, 1989.
3. Segerlind, L.J. "Applied Finite Element Analysis", Wiley Publication, 1984.
4. Reddy J.N., "An Introduction to Finite Element Method", McGraw-Hill Company, 1984.
5. G. Ramamurty, Applied Finite Element Analysis, I. K. International Pvt Ltd, 2010.

Course Code	Course Title						Course Type
OE601EE	**APPLICATIONS OF ELECTRICAL ENERGY**						**Open Elective-I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

CourseObjectives

- To introduce the students and understand Utilization of electrical energy for various applications like industrial heating.
- To understand various techniques of electric welding and types of batteries.
- To understand the concept of illumination and study about the laws of illumination.
- To know the applications of various lamps to factory lighting, street lighting etc.
- To understand the concept of electric traction including speed – time curves of different traction services.

CourseOutcomes: After the completion of this course, the students shall be able to:

1. Identify a suitable heating scheme for a given application.
2. Identify proper welding technique and various characteristics of batteries.
3. Study the nature and production of light and laws related to illumination.
4. Classify types of electric light sources based on nature and operation and their objectives, performance and reliability.
5. Determine the speed-time characteristics of various traction services and also estimate the energy consumption levels at various modes of operation.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1		2								1	1	
CO2	3	1		2								1	1	
CO3	3	1		2								1	1	
CO4	3	1		2								1	1	
CO5	3	1		2								1	1	

UNIT-I

Industrial Heating: Advantages and methods of electric heating. Description, operation and performance of resistance ovens, Design of heating element. High frequency heating, Induction Heating, Induction furnaces, Core type, Coreless furnaces, Dielectric heating. Electric Arc furnaces, Direct Arc furnace, Indirect Arc furnaces.

UNIT II

Electric welding: Classification of electric welding, welding transformer and its rating, various types of Electric arc welding and electric resistance welding.

Batteries: Lead acid batteries, SMF batteries, Construction and maintenance, Charging and rating of batteries.

UNIT III

Illumination: Introduction, nature and production of light, Sensitivity of the eye, Units of light. The inverse square law and cosine law, Solid angle, Lighting calculations, Determination of M.S.C.P, Rousseau‟s construction.

UNIT IV

Types of lamps - Discharge lamps, Sodium vapour lamps, Mercury vapour lamps, Fluorescent lamp. Starting and power factor corrections, stroboscopic effects, Neon signs, Application to factory lighting, Street lighting and Flood lighting.

UNIT V

Electric Traction: System of Electric Traction, Transmission of drive, Systems of track electrification, Traction mechanics, Speed time curves, Tractive effort, Power of Traction motor, Specific energy consumption, Mechanics of train movement, Coefficient of adhesion.

Suggested Reading:

1. Partab H, Art and Science of Utilization of Electric Power, Dhanpat Rai & Sons, 1997.
2. K.B. Raina & S.K. Bhattacharya, Electrical Design, Estimating 1. and Costing, Wiley Eastern Ltd., 1991.
3. Partab H, Modern Electric Traction, Dhanpat Rai & Sons, 2000.
4. B.L.Theraja, A Text Book of Electrical Technology, S.Chand & Company Ltd, Vol-I.

Course Code	Course Title							Course Type
OE602EE	**ELECTRICAL SAFETY MANAGEMENT**							**Open Elective-I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- Understand electrical safety measures, the hazards associated with electric current, and voltage identify different types of electrical shocks
- Understand installation work of electrical plant and equipment. Safety during installation of outdoor switchyard equipment, safety during installation of electrical rotating machines.
- Understand procedure of domestic wirings,to handle different domestic electrical appliances, Procedure of Agricultural pump installation
- Identifies different hazardous zones, classification of equipment enclosure for various hazardous gases, importance of earthing system. Understand Management Safety Policy
- Understand standards on electrical safety, different IE Rules and Acts

Course Outcomes: After the completion of this course, the students shall be able to:

1. Explain the objectives and precautions of Electrical safety, effects of shocks and their prevention.
2. Summarize the safety aspects during installation of plant and equipment.
3. Describe the electrical safety in residential, commercial and agricultural installations.
4. Describe the various Electrical safety in hazardous areas, Equipment earthing and system neutral earthing.
5. State the electrical systems safety management and IE rules.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1		2								1	1	
CO2	3	1		2								1	1	
CO3	3	1		2								1	1	
CO4	3	1		2								1	1	
CO5	3	1		2								1	1	

UNITI

INTRODUCTION TO ELECTRICAL SAFETY, SHOCKS AND THEIR PREVENTION:

Terms and definitions, objectives of safety and security measures, Hazards associated with electric current, and voltage, who is exposed, principles of electrical safety, Approaches to prevent Accidents, scope of subject electrical safety.

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Primary and secondary electrical shocks, possibilities of getting electrical shock and its severity, medical analysis of electric shocks and its effects, shocks due to flash/ Spark over's, prevention of shocks, safety precautions against contact shocks, flash shocks, burns, residential buildings and shops.

UNIT II

SAFETY DURING INSTALLATION OF PLANT AND EQUIPMENT:

Introduction, preliminary preparations, preconditions for start of installation work, during, risks during installation of electrical plant and equipment, safety aspects during installation, field quality and safety during erection, personal protective equipment for erection personnel, installation of a large oil immersed power transformer, installation of outdoor switchyard equipment, safety during installation of electrical rotating machines, drying out and insulation resistance measurement of rotating machines.

UNIT III

ELECTRICAL SAFETY IN RESIDENTIAL, COMMERCIAL AND AGRICULTURAL INSTALLATIONS: Wiring and fitting – Domestic appliances – water tap giving shock – shock from wet wall – fan firing shock – multi-storied building – Temporary installations – Agricultural pump installation – Do's and Don'ts for safety in the use of domestic electrical appliances.

UNIT IV

ELECTRICAL SAFETY IN HAZARDOUS AREAS: Hazardous zones – class 0,1 and 2 – spark, flashovers and corona discharge and functional requirements – Specifications of electrical plants, equipment for hazardous locations – Classification of equipment enclosure for various hazardous gases and vapours – classification of equipment/enclosure for hazardous locations.

UNIT V

SAFETY MANAGEMENT OF ELECTRICAL SYSTEMS: Principles of Safety Management, Management Safety Policy, Safety organization, safety auditing, Motivation to managers, supervisors, employees.

REVIEW OF IE RULES AND ACTS AND THEIR SIGNIFICANCE:

Objective and scope – ground clearances and section clearances – standards on electrical safety - safe limits of current, voltage –Rules regarding first aid and firefighting facility.
The Electricity Act, 2003, (Part1, 2, 3, 4 & 5).

Suggested Reading:

1. S.Rao, Prof. H.L.Saluja, "Electrical safety, fire safety Engineering and safety management", 1st edition
2. Khanna Publishers. New Delhi, 2016 Reprint.
3. Pradeep Chaturvedi, "Energy management policy, planning and utilization", Concept Publishing company, New Delhi, 1997.

Course Code	Course Title						Course Type
OE601EC	**PRINCIPLES OF ELECTRONIC COMMUNICATION SYSTEMS**						**Open Elective-I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives

- Provide an introduction to fundamental concepts in the understanding of Electronic communications systems
- Provide an introduction to network model and some of the network layers including physical layer, data link layer, network layer and transport layer
- Provide an introduction to the evolution of wireless systems and current wireless technologies
- Provide an introduction to fundamental concepts in the understanding of Telecommunication and optical communications systems
- Provide an introduction to fundamental concepts in Analog and Digital Communications

Course Outcomes: On completion of the course, student will be able to

1. Understand the working of analog and digital communication systems.
2. Understand the Data Communication and Networking
3. Understand the concepts of modulation and demodulations
4. Understand the evolution of communication technologies from traditional telephony systems to modern wireless communication systems
5. Understand the principles of optical communications systems

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1		2								1	1	
CO2	3	1		2								1	1	
CO3	3	1		2								1	1	
CO4	3	1		2								1	1	
CO5	3	1		2								1	1	

UNIT-I

Introduction to communication systems: Electromagnetic Frequency Spectrum, Signal and its representation, Elements of Electronic Communications System, Types of Communication Channels, Signal Transmission Concepts-Baseband transmission and Broadband transmission, Communication parameters-Transmitted power, Channel bandwidth and Noise, Need for modulation Signal Radiation and Propagation-Principle of electromagnetic radiation, Types of Antennas, Antenna Parameters and Mechanisms of Propagation.

UNIT-II

Analog and Digital Communications: Amplitude modulation and demodulation, FM modulation and demodulation, Digital converters, Digital modulation schemes – ASK, FSK, PSK, QPSK, Digital demodulation.

UNIT-III

Data Communication and Networking: Network Models, OSI Model, Data Link Layer – Media Access control, Ethernet, Network Layer – Internet Protocol (IPv4/IPv6), Transport Layer – TCP, UDP.

UNIT-IV

Telecommunication Systems: Telephones, Telephone system, Paging systems, Internet Telephony. Optical Communications: Optical Principles, Optical Communication Systems, Fiber –Optic Cables, Optical Transmitters & Receivers, Wavelength Division Multiplexing.

UNIT-V

Wireless Communications: Evolution of Wireless Systems: AMPS, GSM, CDMA, WCDMA, And OFDM. Current Wireless Technologies: Wireless LAN, Bluetooth, PAN and ZigBee, Infrared wireless, RFID communication, UWB, Wireless mesh networks, Vehicular adhoc networks.

Suggested Readings:

1. Louis E. Frenzel, "Principles of Electronic Communication Systems", 3e, McGraw Hill publications, 2008.
2. Behrouz A. Forouzan,"Data Communications and Networking", 5e TMH, 2012.
3. Kennady, Davis, "Electronic Communications systems", 4e, TMH, 1999.
4. Keiser Gerd "Optical Fiber Communication (SIE)",5th Edition, McGraw Hill Education India,2017.
5. Simon Haykin, "Communication Systems", 5th Edition, Wiley publications, 2006.

Course Code	Course Title						Course Type
OE602EC	**Verilog HDL**						**Open Elective-I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives

- To familiarize with various modeling styles: structural, dataflow and behavioral of Verilog HDL
- To develop combinational and sequential circuits using various modeling styles of Verilog HDL
- To design and develop Verilog HDL models of combinational and sequential circuits
- To learn Synthesis and FPGA design flow
- To design and develop real time applications: Booth's multiplier, Divider, hardwired control for basic CPU, FIR filter

Course Outcomes: On completion of the course, student will be able to

1. Implement and distinguish different Verilog HDL modeling styles
2. Construct and analyze Verilog HDL models of combinational and sequential circuits
3. Design and develop Verilog HDL modeling and test bench for digital systems for the given specifications
4. Outline FPGA design flow and timing analysis
5. Understand implementation of real time applications

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1		2								1	1	
CO2	3	1		2								1	1	
CO3	3	1		2								1	1	
CO4	3	1		2								1	1	
CO5	3	1		2								1	1	

Unit- I

Introduction to HDL: Overview and Importance of HDLs, Differences between HLL, HDL and ALP. Design methodologies, Modules, Lexical Conventions, Number Specifications, Strings, Identifiers and Keywords Data types, System task and compiler Directives, Port declaration and port connection rules

UNIT–II

Structural and Dataflow modeling: gate-level modeling, delays, hazards, dataflow modeling: Continuous Assignments, Delays, Expressions, Operators and Operands, Operator Types and Design Examples.

UNIT–III

Behavioral Modeling: Structured Procedures, Procedural Assignments, Timing Controls, Conditional Statements, multi-way branching, Loops, Sequential and Parallel blocks, Generate blocks. Combinational, sequential logic modules Simulation: Types of Simulation, Event driven Simulation and Cycle Based Simulation; design examples.

UNIT-IV

Synthesis and Verification: Tasks and Functions: Differences between Tasks and Functions, Tasks and Functions. Verilog HDL synthesis, synthesis, Application Specific IC (ASIC) and Field Programmable Gate Array (FPGA) design flow. Verification: Timing analysis and Test bench design. Design examples.

UNIT – V

Real time implementations: Fixed-Point Arithmetic modules: Addition, Multiplication, Division, Arithmetic and Logic Unit (ALU), Timer, Universal Asynchronous Receiver and Transmitter (UART), DSP modules: FIR and IIR filters, CPU design: Data path and control units.

Suggested Reading:

1. Samir Palnitkar, —Verilog HDL A Guide to Digital Design and Synthesis, 2nd Edition, Pearson Education, 2006.
2. Ming-Bo Lin, —Digital System Designs and Practices: Using Verilog HDL and FPGA, Wiley India Edition, 2008.
3. J. Bhasker, —A Verilog HDL Primer, 2nd Edition, BS Publications, 2001.

Course Code	Course Title						Course Type
OE601BM	**ENGINEERING APPLICATIONS IN MEDICINE**						**Open Elective -I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- To make the students gain basic knowledge of Human Physiology.
- To make the students learn the applications of various branches of engineering in Medicine.

Course Outcomes: Upon the completion of the course, the students will be able to:

1. Describe the major organ systems of the human body
2. Understand the concepts of bioelectricity and medical instruments
3. Apply solid and fluid mechanics principles to joints and blood flow respectively
4. Learn the need and applications of BCI
5. Analyze and choose proper biomaterial for various applications

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1		2								1	1	
CO2	3	1		2								1	1	
CO3	3	1		2								1	1	
CO4	3	1		2								1	1	
CO5	3	1		2								1	1	

UNIT-I

Evolution of Modern healthcare, Major organ systems- Cardiovascular, Respiratory, Nervous, Skeletal, Muscular. Homeostasis. Physiological signals and their diagnostic importance.

UNIT-II

Bioelectricity-Excitable cells, Resting potential, Action potential, Accommodation, Strength-Duration Curve, Propagation of impulses in myelinated and unmyelinated nerves.
Medical Instrumentation System-Functions, Characteristics, Design Challenges. Signal Processing-QRS detection.

UNIT-III

Solid mechanics-Analysis of muscle force and joint reaction force for the limb joints.
Fluid mechanics-Factors governing and opposing blood flow, Wind-Kessel model, Application of Hagen-Poiseuille flow to blood flow.

UNIT-IV

Brain-Computer Interface: Brain signals for BCIs, Generic setup for a BCI, Feature extraction and Feature translation involved in BCIs. Typical applications-Word forming, Device control.

UNIT-V

Materials and Tissue Replacements-Types of Biomaterials- Metals, Polymers, Ceramics and Composites and their applications in Soft and Hard tissue replacements. Implants-Manufacturing process, Design, fixation.

Suggested Reading:

1. John Enderle, Susan M. Blanchard and Joseph Bronzino, Introduction to Biomedical Engineering, Second Edition, Elsevier, 2005.
2. Ozkaya, Nordin. M, Fundamentals of Biomechanics, Springer International Publishing, 4th Edition, 2017.
3. Khandpur R.S., Handbook of Biomedical Instrumentation, Tata McGraw Hill, 2016.
4. John G.Webster, Medical Instrumentation: Application and Design, John Wiley and Sons Inc., 3rd Ed., 2003.

Course Code	Course Title						Course Type
OE602BM	**HUMAN ASSISTIVE TECHNOLOGIES**						**Open Elective -I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

Course Objectives:

- To extend knowledge of the amputee, of lost and remaining functions affecting locomotion, and to collect information on the best possible medical treatment.
- To improve fitting techniques and practices, including training, so that existing devices might be used with greater comfort and function.
- To develop improved lower-extremity devices.

Course Outcomes: Successfully the student will be able to:

1. Apply fundamental knowledge of engineering in rehabilitation
2. Apply analytical skills to assess and evaluate the need of the end-user
3. Develop self-learning initiatives and integrate learned knowledge for problem solving
4. Understand the basics of robotics and apply their principles in developing prosthetics
5. Apply the knowledge of computers in solving rehabilitation problems

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1		2								1	1	
CO2	3	1		2								1	1	
CO3	3	1		2								1	1	
CO4	3	1		2								1	1	
CO5	3	1		2								1	1	

UNIT- I

Introduction to Rehabilitation Engineering, Definition of Rehabilitation Engineering, Scope and importance of the field, Historical perspective. Interdisciplinary nature and collaboration with healthcare professionals. Physical disabilities: mobility impairments, spinal cord injuries. Cognitive disabilities: learning disabilities, traumatic brain injuries. Psychosocial aspects of disability.

UNIT-II

Assistive Technology, Human Factors and Ergonomics in Assistive Technology Design. Mobility Aids, Types of Wheelchairs and design aspects: Manual wheelchairs, Powered wheelchairs, Customizable features and design considerations, Auxiliary devices and systems. Human-Centered Designing.

UNIT – III

Sensory disabilities: visual and hearing impairments. Sensory augmentation and substitution: Visual system: Visual augmentation. Tactual vision substitution, Auditory vision substitution; Auditory system: Auditory augmentation. Cochlear implantation, Visual auditory substitution, Tactual auditory substitution, Tactual system: Tactual augmentation. Tactual substitution. Assessment and Outcome Measurement

UNIT–IV

Rehabilitation Robotics, Exoskeletons, Major Limb Prosthetic Devices, Orthotic Devices, Types of orthotics and prosthetics, Intelligent prosthetic Knee, Prosthetic Hand, Controlled orthotics and prosthetics Materials and fabrication techniques, Functional and cosmetic considerations. FES system, Restoration of Hand function, Restoration of standing and walking, Myo-electric Hand.

UNIT-V

Case Studies and Real-World Applications. Augmentative and Alternative communications, Software tools for simulation and testing. Virtual reality applications in rehabilitation. Machine learning applications in assistive technology. Predictive analytics for personalized rehabilitation

Suggested Reading:

1. Robinson C.J., *Rehabilitation Engineering*, CRC Press, 1995.
2. Ballabio E., et al., *Rehabilitation Technology*, IOS Press, 1993.
3. Rory A Cooper, Hisaichi Ohnabe, Douglas A. Hobson, *Series in medical physis and biomedical engineering: An introduction to rehabilitation engineering*, Taylor and Francis Group, London, 2007.
4. Joseph D. Bronzino *The biomedical engineering handbook -biomedical engineering fundamentals*, 3rdEd., CRC Press, Taylor & Francis Group, London, 2006.

Course Code	Course Title						Course Type
OE601CS	**PYTHON PROGRAMMING**						**Open Elective -I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
	3	**-**	**-**	**-**	**3**	**40** / **60**	**3**

Course Objectives: The main objective is to teach Computational thinking using Python.

- To know the basics of Programming
- To convert an algorithm into a Python program
- To construct Python programs with control structures.
- To structure a Python Program as a set of functions
- To use Python data structures-lists, tuples, dictionaries.
- To do input/output with files in Python.
- To construct Python programs as a set of objects.

Course Outcomes: On completion of the course, students will be able to:

1. Develop algorithmic solutions to simple computational problems.
2. Develop and execute simple Python programs.
3. Develop simple Python programs for solving problems.
4. Structure a Python program into functions.
5. Represent compound data using Python lists, tuples, dictionaries.
6. Read and write data from/to files in Python Programs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1		2								1	1	
CO2	3	1		2								1	1	
CO3	3	1		2								1	1	
CO4	3	1		2								1	1	
CO5	3	1		2								1	1	

UNIT-I

Introduction to Computing and Problem Solving: Fundamentals of Computing – Computing Devices – Identification of Computational Problems – Pseudo Code and Flowcharts – Instructions – Algorithms – Building Blocks of Algorithms.

Introduction to Python Programming: Python Interpreter and Interactive Mode– Variables and Identifiers – Arithmetic Operators – Values and Types – Statements, Reading Input, Print Output, Type Conversions, thetype () Function and Is Operator, Dynamic and Strongly Typed Language.

Control Flow Statements: The if, The if…else,The if…elif…else Decision Control Statements, Nested if Statement, The while Loop, The for Loop, The continue and break Statements.

UNIT-II

Functions: Built-In Functions, Commonly Used Modules, Function Definition and Calling the Function, The return Statement and void Function, Scope and Lifetime of Variables, Default Parameters, Keyword Arguments, Command Line Arguments.

Strings: Creating and Storing Strings, Basic String Operations, Accessing Characters in String by Index Number, String Slicing and Joining, String Methods, Formatting Strings.

Lists: list operations, list slices, list methods, list loop, mutability, aliasing, cloning lists, list parameters;

Tuples: tuple assignment, tuple as return value; Dictionaries: operations and methods; advanced list processing - list comprehension; Illustrative programs: selection sort, insertion sort, merge sort, histogram.

UNIT- III

Files and Exception: Text files, reading and writing files, format operator; command line arguments, errors and exceptions, handling exceptions, modules, packages; Illustrative programs: word count, copy file.Strings: Basic String Operations, String Slicing, Testing, Searching, and Manipulating Strings Dictionaries and Sets: Dictionaries, Sets, Serializing Objects.

UNIT-IV

Object-Oriented Programming: Classes and Objects, Creating Classes in Python, Creating Objects in Python, The Constructor Method, Classes with Multiple Objects, Class Attributes versus Data Attributes, Encapsulation, Inheritance The Polymorphism.
Functional Programming: Lambda. Iterators, Generators, List Comprehensions.

UNIT-V

GUI Programming: Graphical User Interfaces, Using the tkinter Module, Display text with Label Widgets, Organizing Widgets with Frames, Button Widgets and Info Dialog Boxes, Getting Input with Entry Widget, Using Labels as Output Fields, Radio Buttons, Check Buttons.

Suggested Readings:

1. Richard L. Halterman, “Learning To Program With Python”, Copyright © 2011.
2. Dr. Charles R, “Python for Everybody, Exploring Data Using Python 3”, Severance. 2016.
3. Gowrishankar S., Veena A, “Introduction to Python Programming”, CRC Press, Taylor & Francis Group, 2019.
4. Allen B. Downey,” Think Python: How to Think Like a Computer Scientist‟, 2nd Edition, Shroff O‟Reilly Publishers, 2016.

Course Code	Course Title						Course Type
OE602CS	**CYBER SECURITY**						**Open Elective -I**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation		Credits
	L	**T**	**D**	**P**		**CIE**	**SEE**	
	3	**-**	**-**	**-**	**3**	**40**	**60**	**3**

Course Objectives:

- Learn the various threats in networks and security concepts.
- Apply authentication applications in different networks.
- Understand security services for email.
- Awareness of firewall and IT laws and policies.

Course Outcomes: After Completion of the course, Student will be able to:

1. Understand the various network threats
2. Analyze the forensic tools for evidence collection
3. Apply the firewalls for threat analysis

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1		2								1	1	
CO2	3	1		2								1	1	
CO3	3	1		2								1	1	
CO4	3	1		2								1	1	
CO5	3	1		2								1	1	

UNIT-I

Ethical hacking, Attack Vectors, Cyberspace and Criminal Behaviour, Clarification of Terms, Traditional Problems associated with Computer Crimes, Realms of Cyber world, brief history of the internet, contaminants and destruction of data, unauthorized access, computer intrusions, white-collar crimes, viruses and malicious code, virus attacks, pornography, software piracy, mail bombs, exploitation, stalking and obscenity in internet, Cyber psychology, Social Engineering.

UNIT-II

Introduction to Digital forensics, Forensic software and handling, forensic hardware and handling, analysis and advanced tools, forensic technology and practices, Biometrics: face, iris and fingerprint recognition, Audio-video evidence collection, Preservation and Forensic Analysis.

UNIT-III

Investigation Tools, e-discovery, EDRM Models, digital evidence collection and preservation, email investigation, email tracking, IP tracking, email recovery, search and seizure of computer systems, password cracking.

UNIT-IV

Forensic Analysis of OS artifact, Internet Artifacts, File System Artifacts, Registry Artifacts, Application Artifacts, Report Writing, Mobile Forensic- identification, collection and preservation of mobile evidences, social media analysis, data retrieval, Email analysis from mobile phones.

UNIT-V

Ethics, Policies and IT Act.

Basics of Law and Technology, Introduction to Indian Laws, Scope and Jurisprudence, Digital Signatures, E Commerce-an Introduction, possible crime scenarios, law coverage, data interchange, mobile communication development, smart card and expert systems Indian Laws, Information

Technology Act 2000, Indian Evidence Act, India Technology Amendment Act 2008, Indian Penal Code , Computer Security Act 1987, National Information Infrastructure Protection Act 1996, Fraud Act 1997, Children Online Protection Act 1998, Computer Fraud and Abuse Act 2001, Intellectual Property, IP Theft, Copyright, Trademark, Privacy and Censorship, ,Introduction to Cyber Ethics, rights over intellectual property, Corporate IT Policy Formulations, Compliance Auditing.

Suggested Readings:

1. Charles P. Fleeger, "Security in Computing", Prentice Hall, New Delhi, 2009.
2. BehrouzA.Forouzan, “Cryptography & Network Security”, Tata McGraw Hill, India, New Delhi, 2009.
3. William Stallings, “Cryptography and Network Security”, Prentice Hall, New Delhi, 2006.
4. Chalie Kaufman, Radia Perlman, Mike Speciner, “Network Security: Private Communication in a Public Network”, Pearson Education, New Delhi, 2004.
5. Neal Krawetz, ”Introduction to Network Security”, Thomson Learning, Boston, 2007.
6. Bruce Schneier, “Applied Cryptography”, John Wiley & Sons, New York, 2004.

Course Code	Course Title						Course Type
PC651ME	**METAL CUTTING AND METROLOGY LAB**						**Core**
Prerequisite	Contact hours per week				Duration of SEE	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**	(Hours)	**CIE** / **SEE**	
		-	**-**	**2**	**3**	**25** / **50**	**1**

Course Objectives:

- To have knowledge of various precision measuring instruments.
- To familiarize machining and metal cutting operations.

Course Outcomes: At the end of the course, the student shall be able to:

1. Perform different operations on lathe, Shaper and Milling Machine Tools
2. Perform Finishing operations on flat and curved surfaces
3. Estimate shear angle, stresses involved, power required and tool life in metal cutting
4. Evaluate tolerances, taper angles, roundness, and roughness for a component
5. Calibrate the precision measuring instruments

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	2	1	1		3	2	3	3	1	1	1	1
CO2	3	2	2	1	1		3	2	3	3	1	1	1	1
CO3	3	2	2	1	1		3	2	3	3	1	1	1	1
CO4	3	2	2	1	2	1		2	3	3	1	1	1	1
CO5	3	2	1	1	2	1		2	3	3	1	1	1	1

List of Experiments:

(a) Metrology

1. Linear measurements with inside, outside and depth micrometers, Vernier calipers and Height gauges.
2. Measurement of roundness errors with Bench Centre method and V-block method.
3. Measurement of thread elements with Tool Maker‟s Microscope
4. Measurement of angles with Sinebar, Bevel protractor and Precision level.
5. Tolerance measurement with Electrical Comparator, Mechanical Comparator and GO -No GO Gauge.
6. Calibration of Outside micrometer and Dial gauge.
7. Profile measurement with profile projector
8. Surface roughness measurement using surface roughness tester

(b) Metal Cutting & Machine Tools

1. External & Internal thread cutting on Lathe: single start and multi start threads.
2. V Block machining on Shaper
3. Machining of Square and Hexagonal bolt heads on Milling Machine Tool.
4. Spur Gear cutting on milling machine tool.
5. Study of cylindrical grinding, reaming and burnishing operations
6. Estimation of shear angle by measuring thickness and length of chips.
7. Measurement of Cutting forces with Lathe tool dynamometer and determination of friction angle and stresses on shear plane and rake plane.
8. a) Test for tool life. b) Measurement of Chip-tool interface temperature by thermocouple.

Course Code	Course Title						Course Type
PC652ME	**COMPUTER AIDED ENGINEERING LAB**						**Core**
Prerequisite	Contact hours per week				Duration of SEE (Hours)	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**		**CIE** / **SEE**	
		-	**-**	**2**	**3**	**25** / **50**	**1**

Course Objectives:

- To understand the various features of geometric modelling using standard softwares like Creo(Pro-E) /CATIA/Solid Works like 2d-Sketching, Part Modeling and Assembly.
- To understand the application of Finite Element Analysis using standard packages like ANSYS/ NASTRAN/ADINA in solving structural and thermal problems.

Course Outcomes: The students will be able to

1. Develop models of engineering components and assemblies using Computer Aided Modelling methods and procedures.
2. Simulate/solve structural and thermal problems using standard software
3. Perform modal analysis and determine the natural frequency and mode shapes of Cantilever beam
4. Prepare technical document /report.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	3		3	1		1	3	3		2	3	2
CO2	3	3	3	3	3	1		1	3	3	1	2	2	3
CO3	3	3	2	3	3	1		1	3	3	1	2	3	2
CO4		2	2	1	2	1		1	3	3	2	1	2	2

List of Experiments

ComputerAidedModelling

1. Introduction of Creo and 2D-Sketching.
2. ModellingofParts usingextrude feature
3. Modelling of Parts using revolve feature
4. Modelling of Parts using sweep feature
5. Modelling of Part using blend feature
6. Assembly Modelling

ComputerAidedAnalysis

1. Analysis of Two-Dimensional Truss
2. Analysis of Plane Stress Bracket

3. Analysis of Flat rectangular plate
4. Modal Analysis of a Cantilever Beam
5. Analysis of Simple Conduction problem
6. Analysis of Thermal - Mixed Boundary problem

Course Code	Course Title						Course Type
PC653ME	**MINI PROJECT**						**Core**
Prerequisite	Contact hours per week				Duration of SEE	Scheme of Evaluation	Credits
	L	**T**	**D**	**P**	(Hours)	**CIE** / **SEE**	
		-	**-**	**6**	**3**	**50** / **-**	**3**

Course Outcomes:

1. At the end of the course, students will demonstrate the ability to:
2. Conceive a problem statement either from rigorous literature survey or from the requirements raised from need analysis.
3. Design, implement and test the prototype/algorithm in order to solve the conceived problem.
4. Write comprehensive report on mini project work.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	2	2		2			3	3	2	3	1	1	1
CO2	2	2	2		2			3	3	2	3	1	1	1
CO3	2	2			2		1	3	3	3	2			
CO4														
CO5														

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Guidelines:

1. The mini-project is a team activity having 3-4 students in a team. This is mechanical product design work/ manufacturing process with a focus on mechanical system design/manufacturing process.
2. The mini project may be a complete hardware or a combination of hardware and software. The software part in mini project should be less than 50% of the total work.
3. Mini Project should cater to a small system required in laboratory or real life.
4. It should encompass components, devices, with which functional familiarity is introduced.
5. After interactions with course coordinator and based on comprehensive literature survey/ need analysis, the student shall identify the title and define the aim and objectives of mini-project.
6. Student is expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and submit the proposal within first week of the semester.
7. The student is expected to exert on design, development and testing of the proposed work as per the schedule.
8. Art work and Layout should be made using CAD based software.
9. Completed mini project and documentation in the form of mini project report is to be submitted at the end of semester.

Service Courses Offered to the Department of Electronics and Communication Engineering

FUNDAMENTALS OF ROBOTICS

Credits: 3

Instruction: 3 periods per week — Duration of SEE: 3 hours
CIE: 40 marks — SEE: 60 marks

Course Objectives:

- Familiarize students with various robot configurations.
- Learn to perform forward and inverse kinematics for general robot configurations.
- Familiarize with various trajectory planning and control techniques.
- Will learn to integrate various components in to a robotic system.

Course Outcomes: After completion of the course student will be able to

- Identify and classify various robot configurations with their workspaces & their usage in industry.
- Perform forward and inverse kinematics operations & determine singularity conditions for various robot configurations.
- Implement various path planning techniques & control algorithms for computing end effector motions for generalized robotic tasks.
- Understand and Use appropriate sensors for specified applications.
- Interface various hardware and software components to develop robotic systems for industry including the effects of multiple finger kinematics.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	1	1	1									
CO2	3	2	1	1	1								1	1
CO3	3	2	1	1	1								1	1
CO4	3	2	1	1	1								1	1
CO5	3	2	1	1	1									

UNIT – I

Brief History, Types of robots, Overview of robot subsystems, resolution, repeatability and accuracy, Degrees of freedom of robots, Robot configurations and concept of workspace,

Mechanisms and transmission, End effectors and Different types of grippers, vacuum and other methods of gripping. Pneumatic, hydraulic and electrical actuators, applications of robots, specifications of different industrial robots.

UNIT – II

Rotation matrices, Euler angle and RPY representation, Homogeneous transformation matrices, Denavit-Hartenberg notation, Direct kinematics, Derivation of DH parameters for various robot configurations, Representation of absolute position and orientation in terms of joint parameters,

UNIT – III

Inverse Kinematics, direct v/s inverse kinematics, inverse orientation, inverse locations, Singularities, Determination of Singular conditions for various common robot configurations, Jacobean,

UNIT – IV

Trajectory Planning: joint interpolation, task space interpolation, execution of user specified tasks. Independent joint control, PD and PID feedback, Computed torque control

UNIT – V

Sensors: types of sensors, tactile & non tactile sensors, sensors to measure Position, velocity & acceleration measurement, Optical encoders. Range and Proximity sensing, acoustic, pneumatic, hall effect sensor, Eddy current sensors, Force and Torque sensors. Vision: Image acquisition, types &components of vision system, Image representation, digitization, binary, gray scale, RGB representation, Image processing, Image segmentation, image smoothening, object descriptors, object recognition. Robots used in general applications like material handling, process applications, assembly operations, inspection applications, healthcare, entertainment.

Suggested Readings:

1. Nagrath and Mittal, “Robotics and Control”, Tata McGraw-Hill, 2003.
2. Spong and Vidhyasagar, “Robot Dynamics and Control”, John Wiley and sons, 2008.
3. S K Saha, “Introduction to Robotics “, 2nd edition, TMH, 2013.
4. Harry Asada &Slottine “Robot Analysis& Control” , Wiley Publications, 2014.
5. Fu. K.S, Gonzalez, R.C., Lee, C.S.G, Robotics, control, sensing, Vision and Intelligence, McGraw Hill International, 1987.

A Mathematical Introduction to Robotic Manipulations- Richard M. Murray, Zexiang Li, S.ShankarSastry CRC Press.Inc. 1st edition, 1994.