DEPARTMENT OF MECHANICAL ENGINEERING

Scheme of Instructions

for

V^{th} and VI^{th} Semesters

With Effect from academic year

2020-2021

UNIVERSITY COLLEGE OF ENGINEERING
(AUTONOMOUS)
OSMANIA UNIVERSITY
HYDERABAD-500 007, TELANGANA

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

S. No.	Code	Name of the Course	No of Hours				Scheme of Examination		Credits
			L	T	P	Contact Hrs/wk	CIE	SEE	
1.	PC501ME	Fluid Mechanics & Hydraulic Machines	3	-	-	3	30	70	3
2.	PC502ME	Heat Transfer	3	-	-	3	30	70	3
3.	PC503ME	Dynamics of Machines	3	-	-	3	30	70	3
4.	PC504ME	Machine Design	3	-	-	3	30	70	3
5.	PC505ME	Metal Cutting & Machine Tools	3	-	-	3	30	70	3
6.	PEME	Professional Elective-I	3	-	-	3	30	70	3
PRACTICALS									
7.	PC551ME	Fluid Mechanics & Hydraulic Machines Lab	-	-	3	3	25	50	1.5
8.	PC552ME	Dynamics of Machines Lab	-	-	3	3	25	50	1.5
9.	PR553ME	Project-I/Summer Internship	-	-	2	2	-	-	1
		Total	18	-	8	26	230	520	22

PROFESSIONAL ELECTIVE COURSE -I	
PE501ME	Production Planning and Control
PE502ME	Powder Metallurgy
PE503ME	Robotic Engineering
PE504ME	Theory of Elasticity
PE505ME	Automobile Engineering

Course Code: PC501ME

FLUID MECHANICS AND HYDRAULIC MACHINES

Credits: 3

Instructions: (3L) hrs per week *Duration of SEE: 3hours*
CIE: 30 Marks *SEE: 70 Marks*

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:

CO's	Description	Blooms Level
CO1	Define the properties of fluids and classify the fluids.	L1
CO2	Apply conservation laws to fluid flow problems in engineering applications and examine the stability of a floating bodies.	L3
CO3	Apply Euler's Equation of motion and Bernoulli's equation for flow measuring devices and hydraulic machines.	L3
CO4	Illustrate the working of Hydraulic machines.	L2
CO5	Analyze the performance of various types of Hydraulic pumps and turbines.	L4

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 Bernoullis 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. A.K.Mohanty. "Fluid Mechanics" , PHI Learning Pvt. Ltd, 1994
3. S.K.Som, Gautam Biswas, S Chakraborty. "Introduction to Fluid Mechanics and Fluid Machines", McGraw Hill Education, 2017
4. Bansal, R. K., "Textbook of fluid mechanics and hydraulic machine" Laxmi Publication, 2011
5. Gupta, V., & Gupta, S. K., "Fluid mechanics and its applications", Tunbridge Wells: New Academic Science, 2012
6. Jagdish Lal, "Hydraulic Machines", Metropolitan Book Co., 1994.
7. N.S. Govind Rao, "Fluid Flow Machines, Tata Mc Graw Hill", 1983.
8. K. Subramanya, "Theory and Applications of Fluid Mechanics", Tata McGraw-Hill Publishing Company Ltd.,1993
9. Vijay Gupta and Santosh K. Gupta, "Fluid Mechanics and its applications", Wiley Eastern Ltd.,1984.
10. K.L. Kumar, "Engineering Fluid Mechanics", Eurasia Publishing House Pvt Ltd., New Delhi, 2009.

Articulation Matrix:

CO No.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS O1	PS O2
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	-
CO5	3	3	3	3	1	-	-	-	-	-	-	2	1	-

Course Code: PC502ME

HEAT TRANSFER

Credits: 3

Instructions: (3L) hrs per week — *Duration of SEE: 3hours*
CIE: 30 Marks — *SEE: 70 Marks*

Course Objectives:

- To develop 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:

CO's	Description	Blooms Level
CO1	Illustrate the basic modes of heat transfer with its associated laws in simple geometries.	L2
CO2	Solve the problems of steady state and transient heat conduction with simple and multi-layer geometries.	L3
CO3	Analyze heat transfer coefficients for free and forced convection, considering boundary layers.	L4
CO4	Develop relationships for radiation exchange between (Opaque, Diffuse, Gray) Surfaces in an enclosure, Blackbody radiation exchange.	L3
CO5	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.	L4

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: Absorptivity, Reflectivity, and Transmissivity, Concept of a blackbody, 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

Articulation Matrix:

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

Course Code: PC503ME

DYNAMICS OF MACHINES

Credits: 3

Instructions: (3L) hrs per week *Duration of SEE: 3hours*
CIE: 30 Marks *SEE: 70 Marks*

Course Objectives:

1. To find static and dynamic forces on planar mechanisms.
2. To know the causes and effects of unbalanced forces in machine members.
3. 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:

CO's	Description	Blooms Level
CO1	Compare and contrast various methods of static and dynamic analysis of planar and spatial mechanisms.	L2
CO2	Evaluate Gyroscopic effects on Naval ships, Aeroplanes and Automobile.	L4
CO3	Analyze balancing problems in rotating and reciprocating machinery.	L4
CO4	Design systems like governors and flywheels for controlling speed and energy fluctuations.	L4
CO5	Determine natural frequencies and conditions for resonance of single degree and multi degree systems.	L3

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

Forces on bearings due to rotating shaft carrying several eccentric rotors, balancing of shafts carrying several rotors, determination of balancing masses from the forces on the bearings shaking forces in a single cylinders engine, partial balancing of reciprocating engine. Balancing of a two cylinder locomotive engine, determination of unbalanced forces and couples.

Unit-IV

The role of a centrifugal governor in speed control, Porter and Hartnell type governors, speed vs lift curves, power and stability. Undamped free vibration of a single degree of freedom linear system (axial and torsional), determination of natural frequencies, equivalent system of combination of springs, stepped shafts, gears and rotors. Free response of single degree of freedom damped linear systems, damped natural frequencies, relative damping. Vibration of harmonically forced single degree of freedom systems. Resonance, vibration isolation with coupled damper. Partial differential equation governing free vibration of a simply supported uniform beam. Derivation of natural frequencies.

Unit-V

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.

Suggested Reading:

1. S.S. Rathan, "Theory of Machines", Tata-Mc Graw Hill, 1995.
2. Thomas Bevan, "Theory of Machines", 3rd edition, Pearson Education, 2005
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. Robert L. Norton, "Design of Machinery", Tata Mc Graw Hill, 2005.

Articulation Matrix:

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

Course Code: PC504ME

MACHINE DESIGN

Credits:3

Instructions: (3L) hrs per week *Duration of SEE: 3hours*
CIE: 30 Marks *SEE: 70 Marks*

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:

CO's	Description	Blooms Level
CO1	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.	L2
CO2	Illustrate various mechanical components under different loading conditions & constraints.	L2
CO3	Analyse various mechanical components under simple and combined loads.	L3
CO4	Determine (material, dimensions, shape, number) mechanical components subjected to various types of loads, constraints & failure criterions.	L3
CO5	Design mechanical components for specific applications in industry.	L4

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. P. Kannaiah, "Machine Design", Science-Tech Publications, 2003.
5. M.F. Spotts, "Design of Machine Elements", Prentice Hall, 1964.
6. Robert L. Norton, "Machine Design: An Integrated Approach",2/e PearsonEducation, 2000.
7. Nitin Ghokale, "Practical Finite Element Techniques", Altair Publications.

Articulation Matrix:

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

Course Code: PC505ME

METAL CUTTING AND MACHINE TOOLS

Credits: 3

Instruction: (3L) per week | *Duration of SEE: 3 hours*
CIE: 30 Marks | *SEE: 70 Marks*

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:

CO's	Description	Blooms Level
CO1	Develop the relations for shear angle, shear strain, forces and temperatures associated with orthogonal cutting.	L3
CO2	Select the cutting fluids, tool materials and coatings to control the tool wear and temperature.	L2
CO3	Evaluate the tool life and economics of machining for maximum production and minimum cost.	L4
CO4	Select the appropriate machine tool and tool & work holding devices for machining of components.	L3
CO5	Illustrate the various finishing techniques and unconventional machining processes.	L2

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, 3rdEdition, 2016.
2. B.L. Juneja ,Shekhon G.S. and Seth Nitin, "Fundamentals of Metal Cutting & Machine tools", New Age Publishers, 2003.
3. A. Bhattacharyya, "Metal Cutting Theory and Practice", New Central Book Agency (P) Ltd., 2006.
4. Amitabha Ghosh and Ashok Kumar Mallik, "Manufacturing Science", Affiliated East-West Press Pvt. Ltd., 2ndEdition, 2010.
5. Winston A. Knight and Geoffrey Boothroyd, "Fundamentals of Metal Machining & Machine tools", CRC Press, 3rd Edition, 2005.
6. McGeough JA, "Advanced Methods of Machining", Chapman & Hall, 1988.

Articulation Matrix:

CO No.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO 1	PSO 2
CO1	3	3	2	3	1	-	-	-	-	-	-	1	-	-
CO2	3	3	2	2	2	-	1	-	-	-	-	1	-	-
CO3	3	3	2	2	1	-	-	-	-	-	-	1	1	1
CO4	3	2	2	2	2	-	-	-	-	-	-	1	1	1
CO5	3	2	2	2	1	-	-	-	-	-	-	1	1	1

Course Code: PE501ME

PRODUCTION PLANNING & CONTROL

Credits: 3

Instruction: (3L) per week *Duration of SEE: 3 hours*
CIE: 30 Marks *SEE: 70 Marks*

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:

CO's	Description	Blooms Level
CO1	Identify the objectives, functions, applications of PPC and forecasting techniques.	L2
CO2	Apply different Inventory Control Techniques for determining the optimum inventory.	L3
CO3	Solve routing and scheduling problems.	L3
CO4	Illustrate various types of Line Balancing Techniques and Aggregate Planning Strategies.	L2
CO5	Identify various types of dispatching techniques.	L2

Unit I
Introduction:
Definition – 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 buyers 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 Publishing Corporation, 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.

Articulation Matrix:

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

Course Code: PE502ME

POWDER METALLURGY

Credits: 3

Instruction: (3L) per week — *Duration of SEE: 3 hours*
CIE: 30 Marks — *SEE: 70 Marks*

Course Objectives:
1. To know the various powder manufacturing methods
2. To understand the powder characterization techniques
3. To know the sintering and post sintering practices of powders
4. To learn the pressing and compaction tooling for various powders
5. To know the testing and applications of PM parts in industry

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

CO's	Description	Blooms Level
CO1	Illustrate basic powder production methods of powder metallurgy.	L2
CO2	Identify and characterize the various powders and their properties.	L2
CO3	Apply the sintering technology to develop various PM products.	L3
CO4	Analyze the pressing and sintering tools for powder making.	L4
CO5	Select the testing methods and applications of industrial products manufactured by PM method.	L1

Unit-I:
Introduction: Importance and advantages of Powder Metallurgy. **Powder Manufacture:** Mechanical methods, Solid state reduction, Electrolytic method, thermal decomposition, and Atomization (water atomization, oil atomization, gas atomization, centrifugal atomization).
Powder Characterization: Powder sampling, Properties, Chemical composition, Particle shape, Particle size, Size distribution and Powder density. Compressibility, Green strength. Powder treatment.

Unit-II:
Powder blending/mixing: Lubricant additives, Binder additives, Blending Equipment. **Compaction:** Die compaction, Pressing operation, Compact presses, Factors affecting tooling design, Tooling materials, Design of sintered part, Powder roll compaction, Powder extrusion, Injection moulding. Cold Iso-Static Pressing and Hot Iso-Static Pressing.

Unit-III:
Sintering: Theory of sintering. Sintering practice – Furnace design, Furnace atmospheres, Vacuum sintering, Solid state sintering, Liquid phase sintering, Activated sintering, and loose powder sintering.

Unit-IV:
Post-Sintering Operations: Sizing and Coining, Machining, Infiltration and Impregnation. Heat treatment, hardening, and tempering, Surface hardening, Electro-plating, and Other coatings, Deburring, Joining.

Unit-V:
Testing of PM Parts: Density, Porosity, Microstructure, Hardness, Strength. **Applications:** Porous bearings and filters, Magnetic Materials, Production of Near-net shapes, Rapidly solidified powders, and Spray forming. Manufacturing of Cutting tools, Forming dies using powder metallurgy.

Suggested Reading:

1. P.C Angelo and R. Subramanian, "Powder Metallurgy", Prentice Hall of India Pvt. Ltd., New Delhi, 2nd Edn., 2009.
2. E.P. DeGarmo, J.T. Black and R.A. Kohser, "Materials and Processes in Manufacturing", Prentice Hall of India Pvt. Ltd., New Delhi, 8th Edn., 1997.
3. Anish Upadhyaya and G S Upadhyaya, "Powder Metallurgy", Universities Press, Pvt., Ltd., 2013.
4. Roy A. Lindberg, "Processes and Materials of Manufacture", Prentice Hall of India Pvt. Ltd., New Delhi, 4th Edn., 1995.

Articulation Matrix:

CO NO.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO 1	PSO 2
CO1	3	1	1	1	1	-	-	-	1	-	-	1	-	-
CO2	3	3	1	2	2	-	-	-	-	-	-	1	-	-
CO3	3	1	2	1	2	-	-	-	-	-	-	2	-	1
CO4	3	3	1	2	2	-	-	-	-	-	-	2	-	-
CO5	3	1	1	1	2	-	-	-	-	-	-	1	-	1

Course Code: PE503ME

ROBOTIC ENGINEERING

Credits: 3

Instruction: (3L) per week *Duration of SEE: 3 hours*
CIE: 30 Marks *SEE: 70 Marks*

Course Objectives:

- To provide student with the requisite knowledge of the various sub-disciplines in serial robots such as various robot configurations, kinematics, dynamics, control & manipulation, and computer-based acquisition etc.
- To provide adequate background in both analysis and design of serial robots
- To help students develop robots for needs of industry and society

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

CO's	Description	Blooms Level
CO1	Identify and classify various robot configurations with their workspaces and their usage in industry.	L1
CO2	Perform forward and inverse kinematics operations & determine singularity conditions for various robot configurations.	L3
CO3	Compare and contrast various techniques available to find forward and inverse dynamic solutions for various general robot configurations.	L2
CO4	Implement various path planning techniques & control algorithms for computing end effector motions for generalized robotic tasks.	L4
CO5	Interface various hardware and software components to develop robotic systems for industry & Evaluate their performance.	L4

Unit-I

Brief History, Types of robots, Overview of robot subsystems, Robot specifications, joints and its types, types of links,Degrees of freedom of robots,accuracy, precision, resolution and repeatability, Robot classification: kinematic configurations, actuators, control mechanisms, concept of workspace, End effectors and Grippers, Mechanical, Electrical, vacuum and other methods of gripping. Applications of robots, specifications of different industrial robots.

Unit-II

Rotation matrices, Representation of orientation and translation, Euler angle and RPY representation, Homogeneous transformation matrices, Denavit-Hartenberg notation, representation of absolute position and orientation in terms of joint parameters, direct kinematics.

Unit-III

Angular velocity and acceleration of joints & links, skew symmetric matrices, Inverse Kinematics, inverse orientation, inverse locations, Singularities, Jacobian, Static force analysis of RP type and RR type planar robots, Dynamic analysis using Lagrangian and Newton-Euler formulations of RR and RP type planar robots.

Unit-IV

Trajectory Planning: joint interpolation,task space interpolation, executing user specified tasks, Independent joint control, PD and PID feedback, actuator models, nonlinearity of manipulator models, Computed torque control, force control, hybrid control, neural network based control of manipulator, fuzzy control of manipulator, CNN based control of manipulator.

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. Different types of End effectors for industrial Robots.

Vision: Image acquisition, types & components of vision system, Image representation, digitisation, binary, gray scale, RGB representation, Image processing, Image segementation, image smoothening, object descriptors, object recognition.

Robots used in general applications like material handling, process applications, assembly operations, inspection applications.

Suggested Reading:

1. Spong and Vidyasagar, "Robot Dynamics & Control", John Wiley and Sons, Ed.,1990
2. Mittal and Nagrath, "Industrial Robotics", Tata McGraw Hill Publications, 2004.
3. Saha & Subirkumarsaha, 'robotics', TMH, India.
4. Asada and Sllotine , "Robot analysis and intelligence", BS Publications , India.
5. Fu. K.S., GonZalez R.C., Lee C.S.G. "Robotics, Control-sensing vision and Intelligence", McGraw Hill, Int. Ed., 1987.
6. Groover M P, "Industrial Robotics", McGraw Hill Publications, 1999.
7. Robotics toolbox in MATLAB.
8. Robotic Operating System (ROS), Open source software, ros.org.com.

Articulation Matrix:

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

Course Code: PE504ME

THEORY OF ELASTICITY

Credits: 3

Instruction: (3L) per week *Duration of SEE: 3 hours*
CIE: 30 Marks *SEE: 70 Marks*

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:

CO's	Description	Blooms Level
CO1	Illustrate the basic concepts in continuum mechanics of solids, including of strain, internal force, stress and equilibrium in solids.	L1
CO2	Implementation of energy principles in solution of strength of materials problems.	L3
CO3	Derivation of constitutive relations of plane stress and strain.	L2
CO4	Derivation of stress-strain relations for linearly elastic solids such as beams and plates, and Torsion of shafts.	L4
CO5	Analyze axisymmetric problems such as cylinders and rotating discs and stability of columns.	L4

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 displacements in Cartesian coordinates, Equations of compatibility, Generalized Hook's Law and Lame's constants, Strain energy, Dilatational and distortional energy, St. Venant's principle.

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.

Articulation Matrix:

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

Course Code: PE505ME

AUTOMOBILE ENGINEERING

Credits: 3

Instruction: (3L) per week	*Duration of SEE: 3 hours*
CIE: 30 Marks	*SEE: 70 Marks*

Course Objectives:

- To learn about the layout and arrangement of principal parts of an automobile.
- To understand working of different types of Drive train and Transmission Systems
- To learn about different types of Steering , Axle, Wheels and Tyres.
- To understand different types of Suspension and braking systems.
- To learn about Alternative Energy Sources for Automobiles.

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

CO's	Description	Blooms Level
CO1	Identify principal parts of an automobile and their layout.	L2
CO2	Illustrate the working principles of Drive train and Transmission Systems.	L3
CO3	Enumerate the working principles of Steering, Axle, Wheels and Tyres.	L3
CO4	Examine the functioning of Suspension and braking systems.	L3
CO5	Analyse of alternative Energy Sources for Automobile applications and latest automobiles.	L3

Unit-I

Automobile Body Construction

Automobile history and development, current scenario in Indian auto/ ancillary industries, Classification, types of chassis layout with reference to power source locations and drive, Vehicle frames, Various types of frames. Constructional details, Unitized frame body construction, Loads acting on vehicle frame, details of chassis material.

Unit-II

Drive Train & Transmission

Classification of clutches, Single plate & with dual flywheel effect, Multi plate, Cone, diaphragm spring, Centrifugal, Clutch materials, Clutch plate, Electromagnetic, vacuum operated, Necessity of gear box, Manual gear box-Constant mesh, Sliding mesh, Synchromesh, Epicyclic, fluid flywheel, Torque convertor, Continuous variable transmission (CVT) , Propeller Shaft, Universal Joint, Differential and final drive

Unit-III

Front & Rear Axle, Steering System, Wheel & Tyres

Axle: Purpose and requirement of front & rear axle, live and dead axles types & arrangement, types of loads acting on rear axles, full floating, three quarter floating and semi floating rear axles.

Steering System: Steering mechanism, steering geometry, cornering force, slip angle, scrub radius, steering characteristic, steering linkages & gearbox, power steering, collapsible steering, reversibility of steering, four wheel steering.

Wheel and Tyres: Wheel construction, alloy wheel, wheel alignment and balancing, type of tyres, tyre construction, tyre materials, factors affecting tyre life

Unit-IV

Suspension & Brakes System

Sprung and unsprung mass, types of suspension linkages, types of suspension springs- leaf, coil, air springs, hydro gas, rubber suspension, interconnected suspension, self leveling suspension (active suspension), damping and shock absorbers Types of brake systems - drum, disc, operation-mechanical, hydraulic, air brakes, servo and power braking, hand brake, ABS.

Unit-V
Alternative Energy Sources
Use of Natural Gas, Liquefied Petroleum Gas, Bio-diesel, Bio-ethanol, Gasohol and Hydrogen in Automobiles- Engine modifications required –Performance, Combustion and Emission Characteristics of SI and CI engines with these alternate fuels - Electric and Hybrid Vehicles. Autonomous vehicles –current status of development

Suggested Reading:
1. Kirpal Singh, "Automobile Engineering, Vol I and II",12th Edition, Standard Publishers, 2011
2. S. Srinivasan, "Automotive Mechanics", 2nd Edition, Tata McGraw Hill, 2003.
3. H. Heisler, "Vehicle and Engine Technology", ELBS, 1965.
4. P.L. Kohli, "Automotive Electrical Equipment, Tata McGraw Hill, 1985.
5. William H. Crouse, Donald L. Anglin, "Automotive Mechanics", 10th Ed., Tata Mc Graw Hill, 2007.

Articulation Matrix:

CO No.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	2	1	1	-	-	-	-	-	-	-	-	-
CO2	3	2	2	1	1	-	-	-	-	-	-	-	-	-
CO3	3	2	2	1	1	-	-	-	-	-	-	-	-	-
CO4	3	2	2	1	1	-	-	-	-	-	-	-	-	-
CO5	3	2	2	1	-	1	2	1	-	-	-	-	1	1

PC551ME

FLUID MECHANICS AND HYDRAULIC MACHINERY LABORATORY

Credits: 1.5

Instruction: (3P) per week *Duration of SEE: 3 hours*
CIE: 25 Marks *SEE: 50 Marks*

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:

CO's	Description	Blooms Level
CO1	Illustrate the working of Hydraulic machines.	L2
CO2	Apply the Bernoulli's principle in flow measurement used in hydraulic	L3
CO3	Analyze working principles of hydraulic pumps and turbines.	L4
CO4	Evaluate the theoretical concepts and apply them in the functioning of hydraulic machines	L5
CO5	Estimate the performance of pumps and turbines.	L5

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

Articulation Matrix:

CO No.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS O1	PS O2
CO1	2	1	1	1	-	-	-	-	-	-	-	-	-	-
CO2	3	3	1	2	1	-	-	-	-	-	-	-	-	-
CO3	3	3	3	3	2	-	-	-	-	-	-	-	-	-
CO4	3	3	3	3	2	-	-	-	-	-	-	-	-	-
CO5	3	3	3	3	2	-	-	-	-	-	-	-	1	-

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

S. No.	Code	Name of the Course	No of Hours				Scheme of Examination		Credits
			L	T	P	Contact Hrs/wk	CIE	SEE	
1	PC601ME	Metrology & Instrumentation	3	-	-	3	30	70	3
2	PC602ME	Finite Element Analysis	3	-	-	3	30	70	3
3	PE ME	Professional Elective-II	3	-	-	3	30	70	3
4	PE ME	Professional Elective-III	3	-	-	3	30	70	3
5	HS601MC	Managerial Economics & Accountancy	3	-	-	3	30	70	3
6.	OEC	Open Elective-I	3	-	-	3	30	70	3
PRACTICALS									
7.	PC651ME	Metal Cutting & Metrology Lab	-	-	3	3	25	50	1.5
8.	PC652ME	CAE Lab	-	-	2	2	25	50	1
9.	PR653ME	Project-II	-	-	4	4	25	50	2
		Total	18	-	9	27	255	570	22.5
** At the end of VI semester students should undergo summer Internship - Credits for project III will awarded in VII semester*									

PROFESSIONAL ELECTIVE COURSE-II	
PE601ME	Design of Solar Energy Systems
PE602ME	Refrigeration and Air Conditioning
PE603ME	Control System Theory
PE604ME	Additive Manufacturing Technologies

PROFESSIONAL ELECTIVE COURSE-III	
PE611ME	Mechatronics Systems
PE612ME	Fatigue, Creep and Fracture
PE613ME	Computational Fluid Flows
PE614ME	Non-conventional Machining & Forming Methods

OPEN ELECTIVE COURSE-I	
OE601BM	Engineering Applications in Medicine
OE602CE	Disaster Management
OE603EC	Electronic Instrumentation
OE604EC	Principles of Electronic Communication Systems
OE605ME	3D Printing Technology

Course Code: PC505ME

METROLOGY AND INSTRUMENTATION

Credits: 3

Instruction: (3L) per week — *Duration of SEE: 3 hours*
CIE: 30 Marks — *SEE: 70 Marks*

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:

CO's	Description	Blooms Level
CO1	Illustrate manufacturing process variables.	L1
CO2	Explain the measurement of the physical phenomenon.	L2
CO3	Understand and Apply measurement principles in Industrial requirements.	L3
CO4	Evaluate the methods of measurements affecting Mechanical Engineering	L4
CO5	Design, innovate and modify measuring technology.	L4

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 multijet gauge heads; computation and match gauging.

Unit-II: Optical projector-measurement by comparison, movement and translation, chart gauge types and microgauge 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.

Articulation Matrix:

CO No.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	2	1	1	-	-	-	-	-	-	-	-	-
CO2	3	2	2	1	1	-	-	-	-	-	-	-	-	-
CO3	3	2	2	1	1	-	-	-	-	-	-	-	-	-
CO4	3	2	2	1	1	-	-	-	-	-	-	-	-	-
CO5	3	2	2	1	-	1	2	1	-	-	-	-	1	1

Course Code: PC602ME

FINITE ELEMENT ANALYSIS

(Professional Elective-II)

Credits:3

Instructions: (3L) hrs per week	*Duration of SEE: 3hours*
CIE: 30 Marks	*SEE: 70 Marks*

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:

CO's	Statement	Blooms Level
CO1	Illustrate the concept of Finite Element Method and realize its limitations.	L2
CO2	Construct shape functions for 1D, 2D and 3D linear and higher order elements.	L3
CO3	Applying 1D , 2D and 3D elements to solve different static structural and heat transfer problems.	L3
CO4	Solve 1D and 2D steady state heat transfer, and 1D eigen value and eigen vector problems.	L3
CO5	Analyze time dependent heat transfer problems and review of Finite Element analyses softwares.	L4

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.

Articulation Matrix:

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

Course Code: PE601ME

DESIGN OF SOLAR ENERGY SYSTEMS
(Professional Elective-II)

Credits: 3

Instruction: (3L) per week *Duration of SEE: 3 hours*
CIE: 30 Marks *SEE: 70 Marks*

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 developsolar hybrid systems for different applications.

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

CO's	Description	Blooms Level
CO1	Illustrate solar radiation and its physical function of the measuring devices.	L2
CO2	Compare and contract technologies of solar cell fabrication methods.	L2
CO3	Calculate the required size of solar cell systems for maximum output in peak hours.	L3
CO4	Illustrate the solar thermal system for different applications.	L3
CO5	Evaluate the performance of combined solar thermal and solar cell systems.	L4

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. MertensKonrad, “Photovoltaics : Fundamentals, Technology and Practice”, John Wiley & Sons Inc., 2014.

Articulation Matrix:

	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	2	1	1	-	-	-	-	-	-	1	1	-
CO3	3	3	3	2	2	-	-	-	-	-	-	-	1	1
CO4	3	2	3	2	2	1	-	-	-	-	-	1	1	1
CO5	3	2	2	3	2	1	-	-	-	-	-	1	1	1

Course Code: PE602ME

REFRIGERATION AND AIR CONDITIONING

Credits: 3

Instruction: (3L) per week *Duration of SEE: 3 hours*
CIE: 30 Marks *SEE: 70 Marks*

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:

CO's	Description	Blooms Level
CO1	Distinguish different types of refrigerants and their properties used in the refrigeration cycle.	L2
CO2	Analyze the performance of vapour compression and vapour absorption system	L4
CO3	Distinguish between conventional and non-conventional refrigeration system.	L2
CO4	Apply the principles of Psychrometrics to estimate the air conditioning loads for the industrial applications.	L3
CO5	Illustrate various methods to obtain cryogenic temperatures.	L2

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 cryogenics in metallurgy, cryobiology and cryosurgery.

Suggested Reading:

1. Arora & Domkundwar, " A Course in Refrigeration and Air conditioning", 8th Edition, Dhanpatrai & Co, 2008.
2. Roy J. Dossat, "Principles of Refrigeration", 5th edition, Pearson Education, 2001
3. R.S. Khurmi & J.K. Gupta, "Refrigeration and air conditioning", 5th revised edition, S Chand & Co, 2008.
4. Jordon & Priester, "*Principles of Refrigeration and Air Conditioning*", Prentice Hall, India,1988
5. Arora C.P., "Refrigeration and Air Conditioning", Tata McGraw Hill, New Delhi, 1988.

Articulation Matrix:

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

Course Code: PE603ME

CONTROL SYSTEMS THEORY

(Professional Elective-II)

Credits:3

Instructions: (3L) hrs per week	*Duration of SEE: 3hours*
CIE: 30 Marks	*SEE: 70 Marks*

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:

CO's	Statement	Blooms Level
CO1	Distinguish between open loop and closed systems with examples.	L2
CO2	Develop mathematical models of mechanical, electrical, electro-mechanical systems.	L4
CO3	Evaluate the effects of transient and steady state responses and apply these models to real time systems.	L4
CO4	Apply the time response and frequency response methods to determine the stability of the system.	L3
CO5	Apply the concepts of discrete time control systems. Analyse and design multi input, multi output systems by state space analysis.	L3

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 invariant systems, 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., 4* Edition, 2004.
6. Benjamin kuo, ‘automatic control systems ’, 9th edition, wiley, india, 2010.

Articulation Matrix:

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

Course Code: PE604ME

ADDITIVE MANUFACTURING TECHNOLOGIES

(Professional Elective-II)

Credits:3

Instructions: (3L) hrs per week *Duration of SEE: 3hours*
CIE: 30 Marks *SEE: 70 Marks*

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:

S.No	Statement	Blooms Level
CO1	Interpret the features of Additive Manufacturing (AM) and compare it with conventional CNC Technology.	L2
CO2	Illustrate the working principle, advantages, limitations and applications of various Additive Manufacturing Technologies .	L2
CO3	Interpret various types of errors in STL file and other data formats used in AM and identify the role of Topology optimization in AM.	L3
CO4	Analyze different types of software's used in 3D Printing Technology.	L4
CO5	Apply the knowledge of various AM technologies for developing innovative applications.	L3

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 and Disadvantages, Case studies of the following AM Technologies:

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

Articulation Matrix:

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

Course Code: PE611ME

MECHATRONICS SYSTEMS
(Professional Elective-III)

Credits:3

Instructions: (3L) hrs per week — *Duration of SEE: 3hours*
CIE: 30 Marks — *SEE: 70 Marks*

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:

S.No	Statement	Blooms Level
CO1	Illustrate the architecture of mechatronic systems.	L2
CO2	Design some simple measurement systems using different sensors.	L4
CO3	Demonstrated ability to design basic control systems using different actuators.	L3
CO4	Execute PLC programs for industrial Applications.	L4
CO5	Demonstrate an understanding of analogue and digital interfacing.	L3

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. 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. Devdas Shetty, Richard Klok "Mechatronic system design", 2nd edition, Cengage Learning,
5. Boltan, W., "Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering", Longman, Singapore, 1999

6. Krishna Kant; Computer Based Industrial Control ; Prentice Hall of India Pvt. Ltd. 1999.
7. Herbert Taub & Donald Schilling : Digital Integrated Electronics, McGraw Hill International Edition, 1977.
8. David Alciatoare, Michael Histand, “Introduction to Mechatronics and Measurement Systems”,McGraw Hill, 2002.
9. Haxkworth, “Programmable Logic Controllers-Programming Methods and its Applications”, Pearson India Ltd., 2011.

Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO 1	PSO 2
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

Course Code: PE612ME

FATIGUE CREEP AND FRACTURE

(Professional Elective-III)

Credits:3

Instructions: (3L) hrs per week	*Duration of SEE: 3hours*
CIE: 30 Marks	*SEE: 70 Marks*

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:

S.No	Statement	Blooms Level
CO1	Enumerate the design philosophy and recognize formulate fatigue design.	L2
CO2	Illustrate the factors affecting fatigue and methods to improve fatigue strength.	L2
CO3	Evaluate ductile and brittle fracture.	L4
CO4	Predict the stress field at the crack tip.	L4
CO5	Calculate and measure creep deformation.	L3

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 K_{IC} , 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, Fracture Mechanics

Articulation Matrix:

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

Course Code: PE613ME

COMPUTATIONAL FLUID FLOWS

(Professional Elective-III)

Credits:3

Instructions: (3L) hrs per week — *Duration of SEE: 3hours*
CIE: 30 Marks — *SEE: 70 Marks*

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:

S.No	Statement	Blooms Level
CO1	Establish the governing equations for different types of fluid flow systems.	L3
CO2	Illustrate method of averaging of turbulent flow properties and classify second order partial differential equations.	L2
CO3	Devise finite difference equations based on accuracy, type of differencing and analyse their stability.	L4
CO4	Solve equations using FDM and numerical methods on discretised domain.	L3
CO5	Apply Finite volume method for basic equations of heat transfer and fluid flow problems.	L3

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.

Articulation Matrix:

CO No.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12	PS O1	PS O2
CO1	3	3	2	1	1	-	-	-	-	-	-	-	-	-
CO2	3	2	2	1	1	-	-	-	-	-	-	-	-	-
CO3	3	3	3	3	2	-	-	-	-	-	-	-	-	-
CO4	3	3	3	3	2	-	-	-	-	-	-	1	1	-
CO5	3	3	3	3	2	-	-	-	-	-	-	1	1	-

Course Code: PE614ME

NON-CONVENTIONAL MACHINING & FORMING METHODS

(Professional Elective-III)

Credits:3

Instructions: (3L) hrs per week *Duration of SEE: 3hours*
CIE: 30 Marks *SEE: 70 Marks*

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:

S.No	Statement	Blooms Level
CO1	Illustrate the basic principles of non-conventional machining techniques.	L3
CO2	Select non-conventional machining techniques for various materials.	L2
CO3	Illustrate principles of non-conventional forming techniques.	L3
CO4	Select modern forming processes to various metals.	L2
CO5	Analyze the process parameters of non-conventional machining and forming techniques.	L4

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.

CO No.	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS O1	PS O2
CO1	3	2	1	1	1	-	-	-	-	-	-	-	-	-
CO2	3	3	2	2	1	1	-	-	-	-	-	-	-	-
CO3	3	2	1	1	1	-	-	-	-	-	-	-	-	-
CO4	3	2	2	2	1	1	-	-	-	-	-	-	-	-
CO5	3	3	1	1	2	-	-	-	-	-	-	-	-	-

Course Code: OE601BM

ENGINEERING APPLICATIONS IN MEDICINE

(Open Elective-I)

Credits:3

Instructions: (3L) hrs per week — *Duration of SEE: 3hours*
CIE: 30 Marks — *SEE: 70 Marks*

Course Objectives:

- Provide a basic knowledge of human physiology to engineering graduate students.
- Understand the applications of various branches of engineering in Medicine.

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

1. Importance and evolution of medical health care
2. Applications of solid and fluid mechanics in bio medical systems
3. Evaluation of Brain machine interface based systems
4. understand the characteristics and design challenges in signal processing of bio-mechanical systems
5. Choose replacement materials for various implants

UNIT-I

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

UNIT-II 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 HagenPoiseuille flow to blood flow.

UNIT-III 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-IV 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-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. Joseph D.Bronzino, Biomedical Engineering Fundamentals, 3rd Edition, CRC press, 2006
3. Ozkaya, Nordin. M, Fundamentals of Biomechanics, Springer International Publishing, 4th Edition, 2017.

Course Code: OE 602 CE

DISASTER MANAGEMENT

(Open Elective-I)

Credits:3

Instructions: (3L) hrs per week	*Duration of SEE: 3hours*
CIE: 30 Marks	*SEE: 70 Marks*

Course Objectives:

• To provide students an exposure to disasters, their significance and types.
• To ensure that students begin to understand the relationship between vulnerability, disasters, disaster prevention and risk reduction
• To gain a preliminary understanding of approaches of Disaster Risk Reduction (DRR)
• To enhance awareness of institutional processes in the country and
• To develop rudimentary ability to respond to their surroundings with potential disaster response in areas where they live, with due sensitivity

Course Outcomes:

• The students will be able to understand impact on Natural and manmade disasters.
• Able to classify disasters and destructions due to cyclones
• Able to understand disaster management applied in India

UNIT-I

Introduction to Disasters: Concepts and definitions of Disaster, Hazard, Vulnerability, Resilience, Risks. Natural and Manmade disasters, impact of drought, review of past disasters and drought in India, its classification and characteristics. Classification of drought, causes, Impacts (including social, economic. political, environmental, health, psychosocial, etc.).

UNIT-II

Disaster: Classifications, Causes, Impacts including social, economic, political, environmental, health, psychosocial etc. Differential Impacts - in terms of caste, class, gender, age, location, disability Global trends in disasters, urban disasters, pandemics, complex emergencies, climate change. Cyclones and Floods: Tropical cyclones & Local storms, Destruction by tropical cyclones and local storms, Cumulative atmospheric hazards/ disasters, Cold waves, Heat waves, Causes of floods, Rood hazards in India.

UNIT-III Approaches to Disaster Risk Reduction: Disaster cycle - its analysis, Phases, Culture of safety, prevention, mitigation and preparedness community based DRR, Structuralnonstructural sources, roles and responsibilities of community, Panchayati Raj Institutions/Urban Local Bodies (PRis/ULBs), states, Centre, and other stake-holders.

UNIT-IV Inter-relationship between Disasters and Development: Factors affecting Vulnerabilities, differential impacts, impact of development projects such as darns, embankments, changes in Land-use etc. Climate Change Adaptation, Relevance of indigenous knowledge, appropriate technology and local resources.

UNIT-V Disaster Risk Management in India: Hazard and Vulnerability profile of India Components of Disaster Relief: Water, Food, Sanitation, Shelter, Health, Waste Management Institutional arrangements (Mitigation, Response and Preparedness, OM Act and Policy, other related policies, plans, programmes and legislation) Field Work and Case Studies: The field work is meant for students to understand vulnerabilities and to work on reducing disaster risks and to build a culture of safety. Projects must be conceived creatively based on the geographic location and hazard profile of the region where the college is located.

Suggested Reading :

1. Sharma V. K. (1999). Disaster Management, National Centre for Disaster Management, IIPE, Delhi.
2. Gupta Anil K, and Sreeja S. Nair. (2011). Environmental Knowledge for Disaster Risk Management, NIDM, New Delhi.
3. Nick. (1991). Disaster Management: A Disaster Manager's Handbook. Asian Development Bank, Manila Philippines.
4. Kapur, et al. (2005). Disasters in India Studies of grim reality, Rawat Publishers, Jaipur.
5. Pelling Mark, (2003). The Vulnerability of Cities: Natural Disaster and Social Resilience Earthscan publishers, London.

Course Code: OE 603EC

ELECTRONIC INSTRUMENTATION

(Open Elective-I)

Credits:3

Instructions: (3L) hrs per week — *Duration of SEE: 3hours*
CIE: 30 Marks — *SEE: 70 Marks*

Course Objectives:

1. To familiarize with various measurement parameters and Standards of measurement.
2. To learn the working principles of various types of Microphones and Hygrometers.
3. To understand the operation and applications of CRO.
4. To understand about the operation of various transducers.
5. To understand the importance of biomedical instrumentation and Virtual instrumentation.

Course Outcomes:

1. Analyze the various characteristics of measurement parameters and Standards of measurement.
2. Evaluate the operation and application of microphones
3. Use the CROs for various applications and explore its features.
4. Explore various types of Transducers and their characteristics.
5. Analyze the operation of various biomedical instruments and the features of Virtual Instrumentation.

UNIT – I

Measurement parameters: History of instrumentation. Error in Measurement, Types of Errors, Statistical analysis of errors, Limiting errors, Standards of measurement, IEEE and ISO standards.

UNIT – II

Microphones and Hygrometers: Microphones: Microphones and their types, Humidity measurement, resistive, capacitive, aluminium-oxide and crystal Hygrometer types – Operation and applications.

UNIT – III CRO: Basic Principle of CRT, its features, Block diagram and operation of CRO, Oscilloscope Controls, Waveform display, Measurement of frequency and Phase using Lissajous method, Applications and Advantages of CRO.

UNIT –IV Transducers: Introduction, Electrical Transducer, Factors for Selecting a Transducer, Active and Passive Transducers, Operation and applications of Resistive transducers, Strain gauges and Thermistors.

UNIT –V Biomedical and Virtual Instrumentation: Biomedical instrumentation, Bio-potential electrodes, Principles of operation and applications of ECG, EEG, EMG, X-ray machines, CT scanners and Introduction to virtual instrumentation.

Suggested Reading:

1. Albert D.Helfrick and William D.Cooper, “Modern Electronic Instrumentation and Measurement Techniques”, Prentice-Hall of India Private Limited, New Delhi, 1996.

2. H S Klasi, “Electronic Instrumentation”, Tata McGraw-Hill Company Limited, New Delhi, 2004.
3. David A.Bell, “Electronic Instrumentation and Measurements”, 2nd Edition, PrenticeHall of India Private Limited, New Delhi, 1994.
4. R.S.Khandpur, “Handbook of biomedical Instrumentation”, Tata McGraw- Hill publishing company Limited, New Delhi, 2000.

Course Code: OE 604EC

PRINCIPLES OF ELECTRONIC COMMUNICATION SYSTEMS

(Open Elective-I)

Credits:3

Instructions: (3L) hrs per week *Duration of SEE: 3hours*
CIE: 30 Marks *SEE: 70 Marks*

Course Objectives:

1. Provide an introduction to fundamental concepts in the understanding of communications systems.
2. Provide an introduction to network model and some of the network layers including physical layer, data link layer, network layer and transport layer.
3. Provide an introduction to the evolution of wireless systems and current wireless technologies.

Course Outcomes: Student will be able to

CO1 Understand the working of analog and digital communication systems
C02 Understand the OSI network model and the working of data transmission
CO3 Understand the concepts of modulation and demodulations
CO4 Understand the evolution of communication technologies from traditional telephony systems to modern wireless communication systems.
CO5 Understand the principles of optical communications systems

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.

Course Code: OE605ME

3D PRINTING TECHNOLOGY

(Open Elective-I)

Credits:3

Instructions: (3L) hrs per week | *Duration of SEE: 3hours*
CIE: 30 Marks | *SEE: 70 Marks*

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:

S.No	Statement	Blooms Level
CO1	Interpret the features of 3D Printing and compare it with conventional methods.	L2
CO2	Illustrate the working principle of liquid, solid and powder based 3D Printing Technologies.	L2
CO3	Identify various types of errors in STL file and other data formats used in 3D Printing Technology.	L3
CO4	Select suitable software used in 3D Printing Technology.	L2
CO5	Apply the knowledge of various 3D Printing technologies for developing innovative applications.	L3

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. RafiqNoorani, 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/

Articulation Matrix:

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