For Honors:

I. Machine Design (Any 5 theory and 2 Labs)

1. Advanced Mechanics of Solids
2. Mechanical Vibrations and Acoustics
3. Advanced Finite Element Methods
4. Product Design
5. Geometric Modeling
6. Advanced Mechanisms & Robotics
7. Advanced Machine Design
8. Fracture Mechanics
9. Mechanisms and Robotics Lab
10. Vibration and Acoustics Lab

II. CAD/CAM (Any 5 theory and 2 Labs)

1. Advanced Finite Element Methods
2. Advanced CAD
3. Advanced CAM
4. Optimization & Reliability
5. Mechanical Behavior of Materials
6. Industrial Robotics & Automation
7. Materials Characterization Techniques
8. Product Design and Development
9. CAD/CAM Lab
10. Robotics & Automation Lab

III. Thermal Engineering (Any 5 theory and 2 Labs)

1. Advanced Heat Transfer
2. Advanced Fluid Mechanics
3. Advanced Thermodynamics & Combustion
4. Cryogenic Engineering
5. Turbo Machines
6. Thermal Management in EV Battery and Fuel Cell System
7. Design of Heat Transfer Equipment
8. HVAC Systems
9. Advanced Heat Transfer Lab
10. CFD lab

Honors	ADVANCED MECHANICS OF SOLIDS (Machine Design)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. To understand the concept of theory of elasticity equations for solving various engineering problems
2. To study the failure modes of different structural members.
3. To analyse the internal stresses in curved beams and beams subjected to un-symmetrical bending.
4. To understand the deformations and stresses in non-circular cross section members with torsional loading.
5. To analyse the contact stresses.

UNIT – 1

THEORIES OF STRESS AND STRAIN: Definition of stress at a point, stress notation, principal stresses, other properties, differential equations of motion of a deformable body, deformation of a deformable body, strain theory, principal strains, strain of a volume element, small displacement theory. Stress –strain temperature relations, Elastic response of a solid, Hooke's Law, isotropic elasticity, anisotropic elasticity, initiation of Yield, Yield criteria.

UNIT – 2

FAILURE CRITERIA: Modes of failure, Failure criteria, Excessive deflections, Yield initiation, fracture, Progressive fracture, (High Cycle fatigue for number of cycles $N > 10^6$, buckling. Application of energy methods: Elastic deflections and statically indeterminate members and structures: Principle of stationary potential energy, Castiglione's theorem on deflections, Castiglione's theorem on deflections for linear load deflection relations, deflections of statically determinate structures.

UNIT – 3

UNSYMMETRICAL BENDING: Bending stresses in Beams subjected to Non symmetrical bending; Deflection of straight beams due to non-symmetrical bending.

CURVED BEAM THEORY: Winkler Bach formula for circumferential stress – Limitations – Correction factors –Radial stress in curved beams – closed ring subjected to concentrated and uniform loads-stresses in chain links.

UNIT – 4

TORSION : Linear elastic solution; Prandtl elastic membrane (Soap-Film) Analogy; Narrow rectangular cross Section ;Hollow thin wall torsion members ,Multiply connected Cross Section.

UNIT – 5

CONTACT STRESSES: Introduction; problem of determining contact stresses; Assumptions on which a solution for contact stresses is based; Expressions for principal stresses; Method of computing contact stresses; Deflection of bodies in point contact; Stresses for two bodies in contact over narrow rectangular area (Line contact), Loads normal to area; Stresses for two bodies in line contact, Normal and Tangent to contact area.

TEXT BOOKS:

1. Advanced Mechanics of materials by Boresi& Sidebottom-Wiely International.
2. Theory of elasticity by Timoschenko S.P. and Goodier J.N. McGraw-Hill Publishers 3rd Edition
3. Advanced Mechanics of Solids, L.S Srinath

REFERENCE BOOKS:

1. Advanced strength of materials by Den Hortog J.P.
2. Theory of plates – Timoshenko.
3. Strength of materials & Theory of structures (Vol I & II) by B.C Punmia
4. Strength of materials by Sadhu Singh

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

CO1: Calculate stresses in the machine components and analysing the failure modes.

CO2: Identify the failure modes of different structural members and applying various energy methods for statically determinant and indeterminate structures

CO3: Calculate bending stresses in curved beams and beams subjected to non-symmetrical bending

CO4: Calculate torsional stresses in circular and non-circular cross section members and multi walled thin walled tubes

CO5: Calculate and analyse contact stresses when two bodies are in contact.

Honors	MECHANICAL VIBRATIONS AND ACOUSTICS (Machine Design)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. To impart the basic fundamental knowledge to compute the properties of complex structures to evaluate the overall characteristics in design systems.
2. To imbibe the computational knowledge to find the natural frequencies and mode shapes of various degree of freedom systems to analyse vibration parameters.
3. To disseminate the practical knowledge to solve the real time problems in the field sound and noise measurement.

UNIT – 1

INTRODUCTION: Relevance of and need for vibrational analysis – Basics of SHM - Mathematical modelling of vibrating systems - Discrete and continuous systems - single-degree freedom systems - free and forced vibrations, damped and undamped systems.

UNIT – 2

MULTI DEGREE FREEDOM SYSTEMS: Free and forced vibrations of multi-degree freedom systems in longitudinal, torsional and lateral modes - Matrix methods of solution- normal modes - Orthogonality principle-Energy methods, Eigen values and Eigen vectors

UNIT – 3

CONTINUOUS SYSTEMS: Torsional vibrations – Longitudinal vibration of rods - transverse vibrations of beams - Governing equations of motion - Natural frequencies and normal modes - Energy methods, Introduction to non-linear and random vibrations.

UNIT – 4

BASICS OF ACOUSTICS: Speed of Sound, Wavelength, Frequency, and Wave Number, Acoustic Pressure and Particle Velocity, Acoustic Intensity and Acoustic Energy Density, Spherical Wave propagation, Directivity Factor and Directivity Index, Levels and the Decibel, Addition and subtraction of Sound levels, Octave Bands, Source ranking, Weighting network, Dosage.

UNIT – 5

NOISE MEASUREMENT AND CONTROL: Sound Level Meters, Intensity Level Meters, Octave Band Filters Acoustic Analyzers, Dosimeter, Measurement of Sound Power, Impact of noise on humans, sound absorption and insulation, Noise Sources, Noise control strategy.

TEXT BOOKS:

1. S.S.Rao, “Mechanical Vibrations ", 5th Edition, Prentice Hall, 2011.
2. M.L.Munjal, “Noise and Vibration Control”, World Scientific, 2013.

REFERENCES:

1. W.T. Thomson, M.D. Dahleh and C Padmanabhan, “Theory of Vibration with Applications”, 5th Edition, Pearson Education, 2008.
2. L.Meirovitch, “Elements of vibration Analysis", 2nd Edition, McGraw-Hill, New York, 1985.
3. Beranek and Ver, “Noise and Vibration Control Engineering: Principles and Applications”, John Wiley and Sons, 2006.
4. Randall F. Barron, “Industrial Noise Control and Acoustics”, Marcel Dekker, Inc., 2003.

WEB RESOURCES:

1. http://www.nptel.ac.in/courses/112103111
2. http://www.nptel.ac.in/courses/112103112

COURSE OUTCOMES: At the end of the course, student will be able to

CO1: Explain and idealize the properties of complex structures into lumped parameter models for the overall vibration characteristics in design systems which require dynamical properties like damping, free and forced vibrations response.

CO2: Compute the natural frequencies and mode shapes of a multi degree of freedom system and explain the modal analysis of a vibrating system

CO3: Evaluate the vibration parameters of continuous/elastic body systems for natural frequencies and subsequent mode shapes

CO4: Make a practical experience of basics of sound, noise and vibration as well as their measurement and control strategies.

CO5: Describe the noise measurement by using transducers and able to assess occupational and environmental noise problems.

Honors	ADVANCED FINITE ELEMENT METHODS (Machine Design)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVE:

1. The objective of this course is to learn advanced topics in finite element methods so that this tool can be used for analysis, design, and optimization of engineering systems. The course will focus on nonlinear structural analysis. Various nonlinearities in structural problems will be studied in the mathematical and numerical aspects.

UNIT – 1

FORMULATION TECHNIQUES: Methodology, Engineering problems and governing differential equations, finite elements., Variational methods-potential energy method, Raleigh Ritz method, strong and weak forms, Galerkin and weighted residual methods, calculus of variations, Essential and natural boundary conditions.

UNIT – 2

ONE-DIMENSIONAL ELEMENTS: Bar, trusses, beams and frames, displacements, stresses and temperature effects.

UNIT – 3

TWO DIMENSIONAL PROBLEMS: CST, LST, four noded and eight nodded rectangular elements, Lagrange basis for triangles and rectangles, serendipity interpolation functions. Axisymmetric Problems: Axisymmetric formulations, Element matrices, boundary conditions. Heat Transfer problems: Conduction and convection, examples: - two-dimensional fin.

UNIT – 4

ISOPERIMETRIC FORMULATION: Concepts, sub parametric, super parametric elements, numerical integration, Requirements for convergence, h-refinement and p-refinement, complete and incomplete interpolation functions, Pascal's triangle, Patch test.

FINITE ELEMENTS IN STRUCTURAL ANALYSIS: Static and dynamic analysis, Eigen value problems, and their solution methods, case studies using commercial finite element packages.

UNIT – 5

INTRODUCTION TO NON-LINEAR FINITE ELEMENT ANALYSIS (Syllabus from Ref. 3)

NONLINEAR MATERIAL PROBLEMS (Syllabus from Ref. 2): Introduction, General procedure for solutions of Non- linear Discrete Problems, Nonlinear Constitutive problems in solid mechanics. Non-linear elasticity, Plasticity.

GEOMETRICALLY NON-LINEAR PROBLEMS (Syllabus from Ref. 2)**:** General considerations.

TEXT BOOKS:

1. Chandrubatla & Belagondu, Finite element methods.
2. S.S. Rao ,The Finite Element Method in Engineering, Fifth Edition

REFERENCES:

1. 1.J.N. Reddy, Finite element method in Heat transfer and fluid dynamics, CRC press, 1994.
2. Zienckiwicz O.C. Finite Element Method, McGraw-Hill,Third Edition, 1977.
3. K. J. Bathe, Finite element procedures, Prentice-Hall, 1996.

COURSE OUTCOMES: **At the end of the course, student will be able to**

CO1: Apply Variational methods and weighted residual methods to solve governing equations of different engineering problems.

CO2: Derive elements matrices for one-dimensional elements and solve related engineering problems

CO3: Derive elements matrices for two-dimensional elements and solve related engineering problems

CO4: Apply the concepts of Iso parametric formulation for different finite elements. Solve free vibration problems and heat transfer problems

CO5: Explain the procedures to solve the problems involving material non-linearity and geometrical non-linearity.

Honors	PRODUCT DESIGN (Machine Design)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. Understanding of materials, processes, ergonomics, human behaviour and systems with reference to product design.
2. To develop conceptual thinking, and workshop and computer skills for modelling and simulation of a variety of individual and group projects ranging from basic to the complex.
3. To understand various risks involved through various techniques and perform reliability analysis.
4. To acquaint with different product testing procedures under thermal, vibration, electrical and combined environments.

UNIT – 1

PRODUCT DESIGN PROCESS: Design Process Steps, Morphology of Design. Problem Solving and Decision Making: Problem-Solving Process, Creative Problem Solving, Invention, Brainstorming, Morphological Analysis, Behavioural Aspects of Decision Making, Decision Theory, Decision Matrix, Decision Trees.

MODELING AND SIMULATION: Triz, Role of Models in Engineering Design, Mathematical Modeling, Similitude and Scale Models, Computer Simulation, Geometric Modeling on Computer, Finite-Element Analysis.

UNIT – 2

PRODUCT MANAGEMENT: The operation of product management: Customer focus of product management, product planning process, Levels of strategic planning, Wedge analysis, Opportunity search, Product life cycle Life cycle theory and practice.

PRODUCT DEVELOPMENT: Managing new products, Generating ideas, Sources of product innovation, selecting the best ideas, the political dimension of product design, Managing the product launch and customer feedback.

PRODUCT MANAGERS AND MANUFACTURING: The need for effective relationships, 10The impact of manufacturing processes on product decisions, Prototype planning, Productivity potentials, Management of product quality, Customer service levels.

UNIT – 3

RISK AND RELIABILITY: Risk and Society, Hazard Analysis, Fault Tree Analysis. Failure Analysis and Quality: Causes of Failures, Failure Modes, Failure Mode and Effect Analysis, FMEA Procedure, Classification of Severity, Computation of Criticality Index, Determination of Corrective Action, Sources of Information, Copyright and Copying. Patent Literature.

UNIT – 4

PRODUCT TESTING; thermal, vibration, electrical, and combined environments, temperature testing, vibration testing, test effectiveness. Accelerated testing and data analysis, accelerated factors. Weibull probability plotting, testing with censored data.

UNIT – 5

DESIGN FOR MAINTAINABILITY: Maintenance Concepts and Procedures, Component Reliability, Maintainability and Availability, Fault Isolation in design and Self-Diagnostics. Product Design for Safety, Product Safety and User Safety Concepts, Examples of Safe Designs.

DESIGN STANDARDIZATION AND COST REDUCTION: Standardization Methodology, Benefits of Product Standardization; International, National, Association and Company Level Standards; Parts Modularization

TEXT BOOKS:

1. Engineering Design , George E. Dieter, McGRAW-HILL
2. Product Integrity and Reliability in Design, John W. Evans and Jillian Y. Evans, Springer Verlag

REFERENCES:

1. The Product Management Handbook, Richard S. Handscombe, Mc.GRAW-HILL
2. New Product Design, Ulrich Eppinger
3. Product Design, Kevin Otto.

COURSE OUTCOMES: **At the end of the course, student will be able to**

CO1: Apply creative thinking skills for idea generation
CO2: Translate conceptual ideas into clear sketches
CO3: Present ideas using IT application software and physical model
CO4: Able to identify causes of failure through fault free analysis and perform failure analysis
CO5: Test a product under thermal, vibration, electrical and combined environments.

Honors	GEOMETRIC MODELING (Machine Design)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. Model the 3-D geometric information of machine components including assemblies, and automatically generate 2-D production drawings,
2. Understand the basic analytical fundamentals that are used to create and manipulate geometric models in a computer program,
3. Improve visualization ability of machine components and assemblies before their actual fabrication t hrough modeling, animation, shading, rendering, lighting and coloring, Model complex shapes inclu ding freeform curves and surfaces,
4. Understand the possible applications of the CAD systems in motion analysis, structure analysis, opti mization, rapid prototyping, reverse engineering and virtual engineering Usefulscale CAD software systems designed for geometric modeling of machine components and au tomatic generation of manufacturing information.

UNIT–1: INTRODUCTION: Definition, Explicit and implicit equations, parametric equations.

UNIT–2: CUBIC SPLINES-1: Algebraic and geometric form of cubic spline, tangent vectors, parametric space of a curve, blending functions, four point form, reparametrization, truncating and subdividing of curves. Graphic construction and interpretation, composite pc curves.

UNIT–3: BEZIER CURVES: Bernstein basis, equations of Bezier curves, properties, derivatives.
B-SPLINE CURVES: B-Spline basis, equations, knot vectors, properties, and derivatives.

UNIT–4: SURFACES: Bicubic surfaces, Coon's surfaces, Bezier surfaces, B-Spline surfaces, surfaces of revolutions, Sweep surfaces, ruled surfaces, tabulated cylinder, bilinear surfaces, Gaussian curvature.

UNIT–5: SOLIDS: Tricubic solid, Algebraic and geometric form.
SOLID MODELING CONCEPTS: Wire frames, Boundary representation, half space modeling, spatial cell, cell decomposition, classification problem.

TEXT BOOKS:

1. CAD/CAM by Ibrahim Zeid, Tata McGraw Hill.
2. Elements of Computer Graphics by Roger & Adams Tata McGraw Hill.

REFERENCES:

1. Geometric Modeling by Micheal E. Mortenson, McGraw Hill Publishers
2. Computer Aided Design and Manufacturing, K.Lalit Narayan, K.MallikarjunaRao, MMM Sarcar, PHI Publishers

COURSE OUTCOMES: **At the end of the course, student will be able to**

CO1: Derive parametric equations for simple geometric entities, formulate algebraic and geometric form of a cubic spline.
CO2: Derive equations for Bezier curve.
CO3: Derive equations for B-Spline curve
CO4: Derive parametric representation of analytic and synthetic surfaces
CO5: Understand and implement various schemes used for construction of solid models

Honors	ADVANCED MECHANISMS & ROBOTICS (Machine Design)	L	T	P	C
		3	0	0	3

COURSE OUTCOME:

1. The overall objective of this course is to learn how to analyze the motions of mechanisms, design mechanisms to have given motions, and analyze forces in machines. To find radius of curvature of polodes. In the field of Robotics and stimulate their interests in science and engineering through the participation of the entire engineering design process.

UNIT – 1

ADVANCED KINEMATICS OF PLANE MOTION- I: The Inflection circle; Euler – Savary Equation; Analytical and graphical determination of d_i; Bobillier's Construction; Collineastionaxis; Hartmann's Construction.

ADVANCED KINEMATICS OF PLANE MOTION - II: Polode curvature; Hall's Equation; Polode curvature in the four-bar mechanism; coupler motion; relative motion of the output and input links.

UNIT – 2

INTRODUCTION TO SYNTHESIS-GRAPHICAL METHODS - I: The Four bar linkage; Guiding a body through Two distinct positions; Guiding a body through Three distinct positions; The Roto center triangle ; Guiding a body through Four distinct positions; Burmester's curve.

INTRODUCTION TO SYNTHESIS-GRAPHICAL METHODS - II: Function generation-General discussion; Function generation: Overlay's method; Path generation: Roberts's theorem.

UNIT – 3

INTRODUCTION TO SYNTHESIS - Analytical Methods: Function Generation: Freudenstien's equation, Precision point approximation, Precision – derivative approximation; Path Generation: Synthesis of Four-bar Mechanisms for specified instantaneous condition; Method of components; Synthesis of Four-bar Mechanisms for prescribed extreme values of the angular velocity of driven link; Method of components.

UNIT – 4

MANIPULATOR KINEMATICS: D-H transformation matrix; Direct and Inverse kinematic analysis of Serial manipulators: Articulated, spherical& industrial robot manipulators- PUMA, SCARA, STANFORD ARM, MICROBOT

UNIT – 5

DIFFERENTIAL MOTIONS AND VELOCITIES: Introduction, differential relationship, Jacobian, differential motions of a frame-translations, rotation, rotating about a general axis, differential transformations of a frame. Differential changes between frames, differential motions of a robot and its hand frame, calculation of Jacobian, relation between Jacobian and the differential operator, Inverse Jacobian.

TEXT BOOKS:

1. Jeremy Hirschhorn, Kinematics and Dynamics of plane mechanisms, McGraw-Hill, 1962.
2. L.Sciavicco and B.Siciliano, Modelling and control of Robot manipulators, Second edition, Springer -Verlag, London, 2000.
3. Amitabh Ghosh and Ashok Kumar Mallik, Theory of Mechanisms and Machines. E.W.P.Publishers.

REFERENCES:

1. Allen S.Hall Jr., Kinematics and Linkage Design, PHI, 1964.
2. J.E Shigley and J.J. Uicker Jr., Theory of Machines and Mechanisms, McGraw-Hill, 1995.
3. Joseph Duffy, Analysis of mechanisms and Robot manipulators, Edward Arnold,1980

COURSE OUTCOMES: **At the end of the course, student will be able to**

CO1: Derive the Euler Savary equations and use Hartmann's construction to determine the centre of curvature.

CO2: Design four bar linkages in order that an entire body be guided through two, three, four or five distinct positions.

CO3: Apply the Freudenstein's equation to find the lengths of the links in a four-bar mechanism in order i) to correlate the motions of input and output links through a prescribed function ii) that a point on its floating link trace a path defined with respect to the fixed frame of reference

CO4: Write direct kinematic and indirect kinematic equations for robot manipulators using D-H parameters.

CO5: Write differential kinematic equations for robot manipulators.

Honors	ADVANCED MACHINE DESIGN (Machine Design)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. To make the students learn about the selection of materials for various design criteria
2. To learn about the various failure theories
3. To gain knowledge about how to design component against fatigue
4. To study various surface failures
5. To learn about designing against creep along with the ergonomics

UNIT – 1

DESIGN PHILOSOPHY: Design process, Problem formation, Introduction to product design, various design models-Shigley model, Asimov model and Norton model, Need analysis, Strength considerations -standardization. Creativity and Creative techniques, Material selection in machine design, design for safety and Reliability, concept of product design

UNIT – 2

FAILURE THEORIES: Static failure theories, Distortion energy theory, Maximum shear stress theory, Coulomb-Mohr's theory, Modified Mohr's theory, Fracture mechanics Theory. Fatigue mechanisms, Fatigue failure models, Design for fatigue strength and life, creep: Types of stress variation, design for fluctuating stresses, design for limited cycles, multiple stress cycles

UNIT – 3

FATIGUE FAILURE THEORIES: cumulative fatigue damage, thermal fatigue and shock, harmful and beneficial residual stresses, Yielding and transformation.

UNIT – 4

SURFACE FAILURES: Surface geometry, mating surfaces, oil film and their effects, design values and procedures, adhesive wear, abrasive wear, corrosion wear, surface fatigue, different contacts, dynamic contact stresses, surface fatigue failures, surface fatigue strength.

UNIT – 5

CREEP AND DAMPING: creep phenomenon, creep curve, creep parameters, time temperature parameters and life estimate, energy dissipation in materials.

HUMAN ENGINEERING CONSIDERATIONS: Ergonomics, Modern approaches in design, Ethics in engineering design, Ethical issues considered during engineering design process

TEXT BOOKS:

1. Machine Design an Integrated Approach by Robert L. Norton, Prentice-Hall New Jersey, USA.
2. Mechanical Engineering Design by J.E. Shigley and L.D. Mitchell published by McGraw Hill International Book Company, New Delhi.
3. Mechanical Behaviour of Materials- Norman E.Dowling, Stephen L. Kampe, Milo V.Kral Pearson publishers, 5th edition.

REFERENCES:

1. Fundamentals of machine elements by Hamrock, Schmid and Jacobian, 2nd edition, McGraw- Hill International edition.
2. Product design and development by Karl T. Ulrich and Steven D. Eppinger. 3rd edition, Tata McGraw Hill.
3. Product Design and Manufacturing by A.K. Chitale and R.C. Gupta, Prentice Hall
4. Engineering Design / George E Dieter / McGraw Hill /2008
5. Fundamentals of machine elements/ Hamrock, Schmid and Jacobian/ 2nd edition /McGraw Hill International edition.

COURSE OUTCOMES: **At the end of the course, student will be able to**

CO1: Analyse various design models and product design.

CO2: Identify the failure modes and various fatigue mechanisms of different machine components and life estimation.

CO3: Design the machine components against fatigue loads

CO4: Learn about surface failures.

CO5: Design the machine components against creep.

Honors	FRACTURE MECHANICS (Machine Design)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. Students will have the knowledge of 2D and 3D field equations of elasticity, stress concentrations and Airy stress functions.
2. Students will have a fundamental understanding of linear-elastic fracture mechanics (LEFM), energy release rate; stress intensity factors (SIFs) and will be able to solve elementary LEFM-related problems.
3. Students will understand the crack-tip plasticity and elastic fracture and will be able to solve practical elastic plastic fracture problems using J-Integral methods
4. Students will become familiar with finite elements modeling of fracture problems, crack tip singularity elements, and evaluation of stress and strain at crack tips.
5. Students will be able to analyze stationary cracks and perform crack propagation in 2D linear-elastic mechanical components of arbitrary geometry, and determine SIF using SIF tables and commercially available finite element software.

UNIT – 1

INTRODUCTION: Prediction of mechanical failure. Macroscopic failure modes; brittle and ductile behaviour. Fracture in brittle and ductile materials – characteristics of fracture surfaces; inter-granular and intra-granular failure, cleavage and micro-ductility, growth of fatigue cracks, the ductile/brittle fracture transition temperature for notched and unnotched components. Fracture at elevated temperature.

UNIT – 2

GRIFFITHS ANALYSIS: Concept of energy release rate, G, and fracture energy, R. Modification for ductile materials, loading conditions. Concept of R curves.

LINEAR ELASTIC FRACTURE MECHANICS (LEFM). Three loading modes and the state of stress ahead of the crack tip, stress concentration factor, stress intensity factor and the material parameter the critical stress intensity factor, crack tip plasticity, effect of thickness on fracture toughness.

UNIT – 3

ELASTIC-PLASTIC FRACTURE MECHANICS (EPFM).The definition of alternative failure prediction parameters, Crack Tip Opening Displacement, and the J integral. Measurement of parameters and examples of use.

UNIT – 4

FATIGUE: Definition of terms used to describe fatigue cycles, High Cycle Fatigue, Low Cycle Fatigue, mean stress R ratio, strain and load control. S-N curves. Goodman's rule and Miners rule. Micro mechanisms of fatigue damage, fatigue limits and initiation and propagation control, leading to a consideration of factors enhancing fatigue resistance. Total life and damage tolerant approaches to life prediction

UNIT – 5

CREEP DEFORMATION: The evolution of creep damage, primary, secondary and tertiary creep. Micro-mechanisms of creep in materials and the role of diffusion. Ashby creep deformation maps. Stress dependence of creep – power law dependence. Comparison of creep performance under different conditions – extrapolation and the use of Larson-Miller parameters. Creep-fatigue interactions. Examples.

TEXT BOOKS:

1. T.L. Anderson, Fracture Mechanics Fundamentals and Applications, 2nd Ed. CRC press, (1995)
2. B. Lawn, Fracture of Brittle Solids, Cambridge Solid State Science Series 2nd ed1993.

REFERENCES:

1. J.F. Knott, Fundamentals of Fracture Mechanics, Butterworths (1973)
2. J.F. Knott, P Withey, Worked examples in Fracture Mechanics, Institute of Materials.
3. H.L.Ewald and R.J.H. Wanhill Fracture Mechanics, Edward Arnold, (1984).
4. S. Suresh, Fatigue of Materials, Cambridge University Press, (1998)
5. L.B. Freund and S. Suresh, Thin Film Materials Cambridge University Press,(2003).

COURSE OUTCOMES: At the end of the course, student will be able to

CO1: Explain the concepts of types of failure of materials and the Fracture phenomenon in materials.

CO2: Explain Griffith's realization, Griffith's analysis and energy release rate and predict the crack growth response of linear elastic materials using LEFM

CO3: Characterize crack tip stresses and strains using the J-Integral concept

CO4: Estimate fatigue life using Goodman's rule and Miners rule. Describe mechanisms of fatigue damage.

CO5: Explain effect of creep on damage of materials and the concepts of types of failure of materials and the Fracture phenomenon in materials

Honors	MECHANISMS AND ROBOTICS LAB (Machine Design)	L	T	P	C
		0	0	3	1.5

COURSE OBJECTIVE:

1. The course will develop overall background of the student in interdisciplinary robotic technology with emphasis on mechanical aspects. Mechanisms which can be used in robots, their characteristics, kinematic and dynamic analysis and design will be discussed in detail along with the issues, applications and implementation principles of industrial robotics.

LIST OF EXPERIMENTS

I. KINEMATICS AND DYNAMICS OF MECHANISMS LABORATORY

(Design the following mechanisms and simulate using CATIA Software /ADAMS Software)

1. A RRRR mechanism whose coupler curve will pass through 3 given point.
2. A RRRR mechanism whose coupler will guide a straight line segment through at least three given positions.
3. A RRRR mechanism whose input and output motion is coordinated at at least three given positions.
4. A RRRP mechanism whose coupler will guide a straight line segment through at least three given positions.
5. A RRRP mechanism whose input and output motion is coordinated at least two given positions
6. A RRRP mechanism whose input and output motion is coordinated at least three given positions.
7. A RRRR mechanism whose input and output motion is coordinated at least two given positions.
8. A RRRR mechanism whose coupler curve will pass through 4 given points.
9. A RRRR mechanism whose coupler curve will pass through 3 given points.

II. ROBOTICS LAB

Experiments:

1. To demonstrate Forward and inverse Kinematics of articulated robot
2. To program and perform the following operations by using an articulated robot.
   i. Pick and place operation
   ii. To traverse given path (for arc welding)

COURSE OUTCOMES: **At the end of the course, student will be able to**

CO1: Write programs to perform the pick and place operations and trace a path for arc welding process using any articulated robot

CO2: Demonstrate the procedure for forward and inverse kinematic analysis any articulated robot

CO3: Design planar mechanisms using procedures for path generation and rigid body guidance and simulate the motions using ADAMS software.

Honors	VIBRATIONS AND ACOUSTICS LAB (Machine Design)	L	T	P	C
		0	0	3	1.5

COURSE OBJECTIVES:

1. Determine natural frequency, mode shapes and unbalance (static/dynamic) of mechanical systems.
2. Study the signature of common machinery faults such as unbalance & alignment.

LIST OF EXPERIMENTS:

1. Determination of damped natural frequency of vibration of the vibrating system with different viscous oils.
2. Determination of steady state amplitude of a vibratory system with base excitation.
3. Determination of natural frequency and mode shape of multi degree freedom system.
4. Whirling speed of a shaft
5. Diagnosis of Shaft Misalignment and its Effects using MFS
6. Static Balancing Studies of Rotary Systems using MFS
7. Experimental modal analysis of Beams (ME Scope).
8. Experimental modal analysis of plates (ME Scope).
9. Source directivity measurement
10. Sound power and intensity measurement
11. Sound absorption measurement by impedance tube
12. Sound transmission loss measurement by impedance tube
13. Outdoor Noise Measurements and Hemispherical Divergence

COURSE OUTCOMES: **At the end of the course, student will be able to**

CO1: Estimate the damping coefficient of a viscous damper and its effect on the free vibration of a single degree of freedom system.

CO2: Perform forced vibration analysis of discrete and continuous systems using measurement instruments VFT

CO3: Demonstrate experimental modal analysis on different of beams and plates with variable boundary condition.

CO4: Identify the shaft misalignment and rotary unbalance using Machine fault simulator

CO5: Measure acoustic parameters and outdoor noise

Honors	ADVANCED FINITE ELEMENT METHODS (CAD/CAM)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVE:

1. The objective of this course is to learn advanced topics in finite element methods so that this tool can be used for analysis, design, and optimization of engineering systems. The course will focus on nonlinear structural analysis. Various nonlinearities in structural problems will be studied in the mathematical and numerical aspects.

UNIT – 1

FORMULATION TECHNIQUES: Methodology, Engineering problems and governing differential equations, finite elements., Variational methods-potential energy method, Raleigh Ritz method, strong and weak forms, Galerkin and weighted residual methods, calculus of variations, Essential and natural boundary conditions.

UNIT – 2

ONE-DIMENSIONAL ELEMENTS: Bar, trusses, beams and frames, displacements, stresses and temperature effects.

UNIT – 3

TWO DIMENSIONAL PROBLEMS: CST, LST, four noded and eight nodded rectangular elements, Lagrange basis for triangles and rectangles, serendipity interpolation functions. Axisymmetric Problems: Axisymmetric formulations, Element matrices, boundary conditions.

HEAT TRANSFER PROBLEMS: Conduction and convection, examples: - two-dimensional fin.

UNIT – 4

ISOPARAMETRIC FORMULATION: Concepts, sub parametric, super parametric elements, numerical integration, Requirements for convergence, h-refinement and p-refinement, complete and incomplete interpolation functions, Pascal’s triangle, Patch test.

FINITE ELEMENTS IN STRUCTURAL ANALYSIS: Static and dynamic analysis, Eigen value problems, and their solution methods, case studies using commercial finite element packages.

UNIT – 5

Introduction to Non-linear finite element Analysis (Syllabus from Ref. 3)

Nonlinear Material Problems (Syllabus from Ref. 2)**:** Introduction, General procedure for solutions of Non- linear Discrete Problems, Nonlinear Constitutive problems in solid mechanics. Non-linear elasticity, Plasticity.

Geometrically Non-linear problems (Syllabus from Ref. 2): General considerations

TEXT BOOKS:

1. Chandrubatla & Belagondu, Finite element methods.
2. S.S. Rao ,The Finite Element Method in Engineering, Fifth Edition

REFERENCES:

1. J.N. Reddy, Finite element method in Heat transfer and fluid dynamics, CRC press, 1994.
2. Zienckiwicz O.C. Finite Element Method, McGraw-Hill,Third Edition, 1977.
3. K. J. Bathe, Finite element procedures, Prentice-Hall, 1996.

COURSE OUTCOMES: **At the end of the course, student will be able to**

CO1: Apply Variational methods and weighted residual methods to solve governing equations of different engineering problems.

CO2: Derive elements matrices for one-dimensional elements and solve related engineering problems

CO3: Derive elements matrices for two-dimensional elements and solve related engineering problems

CO4: Apply the concepts of Isoparametric formulation for different finite elements. Solve free vibration problems and heat transfer problems

CO5: Explain the procedures to solve the problems involving material non-linearity and geometrical non-linearity.

Honors	ADVANCED CAD (CAD/CAM)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. Model the 3-D geometric information of machine components including assemblies, and automatically generate 2-D production drawings,
2. Understand the basic analytical fundamentals that are used to create and manipulate geometric models in a computer program,
3. Improve visualization ability of machine components and assemblies before their actual fabrication th rough modeling, animation, shading, rendering, lighting and coloring, Model complex shapes includin g freeform curves and surfaces,
4. Understand the possible applications of the CAD systems in motion analysis, structure analysis, optim ization, rapid prototyping, reverse engineering and virtual engineerin
5. Use fullscale CAD software systems designed for geometric modeling of machine components and au tomatic generation of manufacturing information.

UNIT – 1

INTRODUCTION: Definition, Explicit and implicit equations, parametric equations.

UNIT – 2

CUBIC SPLINES-1: Algebraic and geometric form of cubic spline, tangent vectors, parametric space of a curve, blending functions, four point form, reparametrization, truncating and subdividing of curves. Graphic construction and interpretation, composite pc curves.

UNIT – 3

BEZIER CURVES: Bernstein basis, equations of Bezier curves, properties, derivatives.
B-Spline Curves: B-Spline basis, equations, knot vectors, properties, and derivatives.

UNIT – 4

SURFACES: Bicubic surfaces, Coon's surfaces, Bezier surfaces, B-Spline surfaces, surfaces of revolutions, Sweep surfaces, ruled surfaces, tabulated cylinder, bilinear surfaces, Gaussian curvature.

UNIT – 5

SOLIDS: Tricubic solid, Algebraic and geometric form.
SOLID MODELING CONCEPTS: Wire frames, Boundary representation, Half space modeling, spatial cell, cell decomposition, classification problem.

TEXT BOOKS:

1. CAD/CAM by Ibrahim Zeid, Tata McGraw Hill.
2. Elements of Computer Graphics by Roger & Adams Tata McGraw Hill.

REFERENCES:

1. Geometric Modeling by Micheal E. Mortenson, McGraw Hill Publishers
2. Computer Aided Design and Manufacturing, K.Lalit Narayan, K.MallikarjunaRao, MMM Sarcar, PHI Publishers

COURSE OUTCOMES: **At the end of the course, student will be able to**

CO1: Derive parametric equations for simple geometric entities, formulate algebraic and geometric form of a cubic spline.

CO2: Derive equations for Bezier curve.

CO3: Derive equations for B-Spline curve

CO4: Derive parametric representation of analytic and synthetic surfaces

CO5: Understand and implement various schemes used for construction of solid models

Honors	ADVANCED CAM (CAD/CAM)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. To introduce the fundamentals of computer-aided programming (APT, NC) and demonstrate their application in modern manufacturing.
2. To provide knowledge of various CNC tooling systems and adaptive control technologies used in precision machining.
3. To understand the concept, structure, and implementation of post processors for CNC machines.
4. To explore the hardware and software fundamentals of microcontrollers and programmable logic controllers (PLCs), and their applications in CNC automation.
5. To impart knowledge about computer-aided process planning, inspection, and testing methods including the role of AI and expert systems in CAD/CAM systems.

UNIT – 1 **COMPUTER AIDED PROGRAMMING:** General information, APT programming, Examples Apt programming problems (2D machining only). NC programming on CAD/CAM systems, the design and implementation of post processors .Introduction to CAD/CAM software, Automatic Tool Path generation.

UNIT – 2 **TOOLING FOR CNC MACHINES:** Interchangeable tooling system, preset and qualified toois, coolant fed tooling system, modular fixturing, quick change tooling system, automatic head changers. DNC Systems and Adaptive Control: Introduction, type of DNC systems, advantages arid disadvantages of DNC, adaptive control with optimization, Adaptive control with constrains, Adaptive control of machining processes like turning, grinding.

UNIT – 3 **POST PROCESSORS FOR CNC:** Introduction to Post Processors: The necessity of a Post Processor, the general structure of a Post Processor, the functions of a Post Processor, DAPP — based- Post Processor: Communication channels and major variables in the DAPP — based Post Processor, th creation of a DAPP — Based Post Processor.

UNIT – 4 **MICRO CONTROLLERS:** Introduction, Hardware components, I/O pins, ports, external memory: counters, timers and serial data I/O interrupts. Selection of Micro Controllers Embedded Controllers, Applications and Programming of Micro Controllers. Programmable Logic Controllers (PLC' s): Introduction, Hardware components of PLC, System, basic structure, principle of operations, Programming mnemonics timers, Internal relays and counters, Applications of PLC's in CNC Machines.

UNIT – 5 **COMPUTER AIDED PROCESS PLANNING:** Hybrid CAAP System, Computer Aided Inspection and quality control, Coordinate Measuring Machine, Limitations of CMM, Computer Aided Testing, Optical Inspection Methods, Artificial Intelligence and expert system: Artificial Neural Networks, Artificial Intelligence in CAD, Experts systems and its structures.

TEXT BOOKS:

1. Computer Control of Manufacturing Systems / Yoram Koren / Mc Graw Hill. 1983.
2. CAD/CAM Principles and Applications, P.N.Rao, TMH

REFERENCES:

1. Computer Aided Design Manufacturing – K. Lalit Narayan, K. Mallikarjuna Rao and M.M.M. Sarcar, PHI, 2008.
2. CAD / CAM Theory and Practice,/ Ibrahim Zeid,TMH
3. CAD / CAM / CIM, Radhakrishnan and Subramanian, New Age
4. Principles of Computer Aided Design and Manufacturing, Farid Amirouche, Pearson
5. Computer Numerical Control Concepts and programming, Warren S Seames, Thomson.

COURSE OUTCOMES: By the end of this course, the student will be able to:

- **CO1:** Develop and analyze APT and NC programs for 2D machining and generate tool paths using CAD/CAM systems.
- **CO2:** Identify and apply appropriate CNC tooling systems, and evaluate the benefits of DNC systems and adaptive control in machining.
- **CO3:** Design and implement post processors for CNC machines and explain the working of DAPP-based post processor systems.
- **CO4:** Describe the architecture and working of microcontrollers and PLCs and develop basic programs for CNC machine control applications.
- **CO5:** Apply computer-aided process planning techniques and utilize inspection systems such as CMM and optical tools; understand the integration of AI and expert systems in CAD/CAM environments.

Honors	OPTIMIZATION AND RELIABILITY (CAD/CAM)	L	T	P	C
		3	0	0	3

Course Objectives

- To impart the knowledge on classical optimization techniques
- To solve engineering problems using numerical methods for optimization
- To understand genetic algorithms and genetic programming
- To get knowledge about applications of optimization techniques in design and manufacturing systems
- To gain knowledge about the reliability concepts.

UNIT – 1 **Classical Optimization Techniques:** Single variable optimization with and without constraints, multi – variable optimization without constraints, multi – variable optimization with constraints – method of Lagrange multipliers, Kuhn- Tucker conditions, merits and demerits of classical optimization technique.

UNIT – 2 **Numerical Methods for Optimization:** Nelder Mead's Simplex search method, Gradient of a function, Steepest descent method, Newton's method, Pattern search methods, conjugate method, types of penalty methods for handling constraints, advantages of numerical methods.

UNIT – 3 **Genetic Algorithm (GA) :** Differences and similarities between conventional and evolutionary algorithms, working principle, reproduction, crossover, mutation, termination criteria, different reproduction and crossover operators, GA for constrained optimization, draw backs of GA,

Genetic Programming (GP): Principles of genetic programming, terminal sets, functional sets, differences between GA & GP, random population generation, solving differential equations using GP.

Multi-Objective GA: Pareto's analysis, non-dominated front, multi – objective GA, Non-dominated sorted GA, convergence criterion, applications of multi- objective problems.

UNIT – 4 **Applications of Optimization in Design and Manufacturing Systems:** Some typical applications like optimization of path synthesis of a four-bar mechanism, minimization of weight of a cantilever beam, optimization of springs and gears, general optimization model of a machining process, optimization of arc welding parameters, and general procedure in optimizing machining operations sequence.

UNIT – 5 **Reliability:** Concepts of Engineering Statistics, risk and reliability, probabilistic approach to design, reliability theory, design for reliability, numerical problems, hazard analysis.

TEXTBOOKS:

1. Optimization for Engineering Design – Kalyan Moy Deb, PHI Publishers.
2. Engineering Optimization – S. S. Rao, New Age Publishers.
3. Reliability Engineering by L. S. Srinath.
4. Multi objective genetic algorithm by Kalyan Moy Deb, PHI Publishers.

REFERENCE BOOKS:

1. Genetic algorithms in Search, Optimization, and Machine learning – D. E. Goldberg, Addison-Wesley Publishers.
2. Multi objective Genetic algorithms - Kalyan Moy Deb, PHI Publishers.
3. Optimal design – Jasbir Arora, Mc Graw Hill (International) Publishers.
4. An Introduction to Reliability and Maintainability Engineering by CE Ebeling, Waveland Printers Inc., 2009
5. Reliability Theory and Practice by I Bazovsky, Dover Publications, 2013

COURSE OUTCOMES: By the end of this course, the student will be able to:

CO1: Apply the theory of optimization methods and algorithms to develop and for solving various types of optimization problems.

CO2: Apply numerous numerical methods to solve the engineering problems for optimization.

CO3: Apply GA and GP optimization methods to solve the differential equations and analyse the differences between GA and GP.

CO4: Apply optimization techniques to design and manufacturing systems for the optimisation of process parameters.

CO5: Understand and apply major concepts of reliability in engineering design for analysing the statistical experiments leading to reliability modelling.

Honors	MECHANICAL BEHAVIOUR OF MATERIALS (CAD/CAM)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

- To teach students the mechanical properties and behaviour of materials.
- To develop the student's ability to understand and apply the various theories of stress and strain in three dimensions along with the applications.
- To train students to identify, formulate, and solve engineering problems involving resistance to plastic deformation, fatigue, and fracture.

UNIT – 1 Elasticity in metals, mechanism of plastic deformation, slip and twinning, role of dislocations, yield stress, shear strength of perfect and real crystals, strengthening mechanism, work hardening, solid solution, grain boundary strengthening. Poly phase mixture, precipitation, particle, fiber and dispersion strengthening, effect of temperature, strain and strain rate on plastic behaviour, super plasticity, Yield criteria: Von-mises and Tresca criteria.

UNIT – 2 Griffth's Theory, stress intensity factor and fracture Toughness, Toughening Mechanisms, Ductile and Brittle transition in steel, High Temperature Fracture, Creep, Larson – Miller parameter, Deformation and Fracture mechanism maps.

UNIT – 3 Fatigue, fatigue limit, features of fatigue fracture, Low and High cycle fatigue test, Crack Initiation and Propagation mechanism and Paris Law, Effect of surface and metallurgical parameters on Fatigue, Fracture of non-metallic materials, fatigue analysis, Sources of failure, procedure of failure analysis. Motivation for selection, cost basis and service requirements, Selection for Mechanical Properties, Strength, Toughness, Fatigue and Creep.

UNIT – 4 Dual Phase Steels, Micro alloyed, High Strength Low alloy (HSLA) Steel, Transformation induced plasticity (TRIP) Steel, Maraging Steel, Inter metallics, Ni and Ti Aluminides.
Processing and applications of Smart Materials, Shape Memory alloys, Metallic Glass Quasi Crystal and Nano Crystalline Materials, High Entropy alloys.

UNIT – 5 Polymeric materials and their molecular structures, Production Techniques for Fibers, Foams, Adhesives and Coatings; Structure, Properties and Applications of Engineering Polymers; Advanced Structural Ceramics- WC, TiC, TaC, $A1_2O_3$, SiC, Si_3N_4, CBN and Diamond – properties, Processing and applications.

TEXTBOOKS:

1. Mechanical Behavior of Materials/ Thomas H. Courtney/ McGraw Hill/2nd Edition/2000.
2. Mechanical Metallurgy/George E. Dieter/McGraw Hill, 1998.
3. Material Science and Engineering/William D Callister/John Wiley and Sons.

REFERENCE BOOKS:

1. Selection and use of Engineering Materials 3e/Charles J.A/Butterworth Heiremann.
2. Engineering Materials Technology/James A Jacob Thomas F Kilduff/Pearson.
3. Material Science and Engineering/William D Callister/John Wiley and Sons.
4. Introduction to Ceramics, 2nd Edition by W. David Kingery, H. K. Bowen, Donald R. Uhlmann.

COURSE OUTCOMES: By the end of this course, the student will be able to:

CO1: Describe effects of elasticity and plastic deformation on mechanical properties of engineering materials subjected to various static and dynamic loadings.

CO2: Apply the Griffith's theory to different materials to analyse the fracture toughness and stress intensity factor on their performance.

CO3: Analyse the effect of various metallurgical properties on the engineering materials subjected to fatigue and creep.

CO4: Identify modern metallic materials for the various engineering applications.

CO5: Describe the properties, processing and applications of polymer–matrix and ceramic–matrix composites.

Honors	INDUSTRIAL ROBOTICS AND AUTOMATION (CAD/CAM)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

- To introduce Robotics and Automation including robot classification, design and selection, analysis and applications in industry.
- To provide information on various types of end effectors, their design, interfacing and selection.
- To provide the details of operations for a variety of sensory devices that are used on robot.
- To familiarize the basic concepts of transformations performed by robot, to perform kinematics and gain knowledge on programming of robots.

UNIT – 1 **Introduction**: Automation and Robotics, Robot anatomy, robot configuration, motions joint notation scheme, work volume, robot drive systems, control systems and dynamic performance, precision of movement.

Control System and Components: basic concepts and motion controllers, control system analysis, robot actuation and feedback components.

Sensors: Desirable features, tactile, proximity and range sensors, uses sensors in robotics. Positions sensors, velocity sensors, actuators, power transmission systems

UNIT – 2 **Motion Analysis and Control:** Manipulator kinematics, position representation, forward and inverse transformations, homogeneous transformations, manipulator path control, robot arm dynamics, configuration of a robot controller. Robot joint control design.

UNIT – 3 **End Effectors:** Grippers-types, operation, mechanism, force analysis, tools as end effectors consideration in gripper selection and design.

Machine Vision: Functions, Sensing and Digitizing-imaging devices, Lighting techniques, Analog to digital single conversion, image storage: Image processing and Analysis-image data reduction, Segmentation, feature extraction, Object recognition. Training the vision system, Robotic application.

UNIT – 4 **Robot Programming:** Lead through programming, Robot program as a path in space, Motion interpolation, WAIT, SIGNAL AND DELAY commands, Branching, capabilities and Limitations of lead through methods.

Robot Languages: Textual robot Languages, Generations of robot programming languages, Robot language structures, Elements and function.

UNIT – 5 **Robot Cell Design and Control**: Robot cell layouts-Robot centered cell, In-line robot cell, Considerations in work design, Work and control, Interlocks, Error detection, Work cell controller.

Robot Applications: Material transfer, Machine loading/unloading, Processing operation, Assembly and Inspection, Future Application

TEXTBOOKS:

1. Industrial Robotics / Groover M P /Pearson Edu.
2. Introduction to Robotic Mechanics and Control by JJ Craig, Pearson, 3rd edition.

REFERENCE BOOKS:

1. Robotics / Fu K S/ McGraw Hill.
2. Robotic Engineering / Richard D. Klafter, Prentice Hall.
3. Robot Analysis and Intelligence / Asada and Slotine / Wiley Inter-Science.
4. Robot Dynamics & Control – Mark W. Spong and M. Vidyasagar / John Wiley .
5. Introduction to Robotics by SK Saha, The McGrah Hill Company, 6th, 2012.
6. Robotics and Control / Mittal R K &Nagrath I J / TMH.

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

CO1: Figure out, demonstrate the terminologies related to robotics technology, hardware components and apply logic for selection of robotic sub systems and systems.

CO2: Apply the spatial transformations to evaluate forward Kinematics, inverse kinematics and Jacobian for serial and parallel robots.

CO3: Demonstrate knowledge of end effectors, design considerations and the interpretation of data from data acquisition systems.

CO4: Apply the fundamental knowledge of robot programming methods to write small programs for desired application.

CO5: Apply and design robot cell layouts and analyse their applications in various fields.

Honors	MATERIAL CHARACTERISATION TECHNIQUES (CAD/CAM)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

- To provide an introduction about the materials characterization and its importance.
- To impart the knowledge about different types of characterization techniques and their use in reviewing the crystal structure.
- To provide the application knowledge of the properties and behaviour of x-rays and their use in materials characterization and use of TEM and SEM.

UNIT – 1 **Optical Microscopy**– Introduction, Optical principles, Instrumentation, Specimen preparation-metallographic principles, Imaging Modes, Applications and Limitations.
Transmission Electron Microscopy (TEM)– Introduction, Instrumentation, Specimen preparation-pre thinning, final thinning, Image modes- mass density contrast, diffraction contrast, phase contrast, Applications and Limitations.

UNIT – 2 **Scanning Electron Microscopy (SEM)**– Introduction, Instrumentation, Contrast formation, Operational variables, Specimen preparation, imaging modes, Applications and Limitations.
X- Ray Diffraction (XRD)– Introduction, Basic principles of diffraction, X - ray generation, Instrumentation, Types of analysis, Data collection for analysis, Applications and Limitations.

UNIT – 3 **Scanning Probe Microscopy (SPM) & Atomic Force Microscopy (AFM)**– Introduction, Instrumentation, Scanning Tunnelling Microscopy-Basics, probe tips, working environment, operational modes, Applications and Limitations.
Electron Probe Micro Analyser (EPMA) – Introduction, Sample preparation, Working procedure, Applications and Limitations.

UNIT – 4 **X-Ray Spectroscopy for Elemental Analysis**– Introduction, Characteristics of X- rays, X- ray Fluorescence Spectrometry, Wavelength Dispersive Spectroscopy-Instrumentation, Working procedure, Applications and Limitations.

UNIT – 5 **Energy Dispersive Spectroscopy** – Instrumentation, working procedure, Applications and Limitations.
Thermal Analysis– Instrumentation, experimental parameters, Different types used for analysis, Differential thermal analysis, Differential Scanning Calorimetry. Basic principles, Instrumentation, working principles, Applications and Limitations.

TEXTBOOKS:

1. Yang Leng: Materials Characterization-Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia) Pte Ltd., 2008.
2. Robert F. Speyer: Thermal Analysis of Materials, Marcel Dekker Inc., New York, 1994.
3. V. T. Cherapin and A. K. Mallik: Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.
4. ASM Handbook: Materials Characterization, ASM International, 2008.

COURSE OUTCOMES: By the end of this course, the student will be able to:

CO1: Apply appropriate characterization techniques for microstructure examination at different magnification level and use them to understand the microstructure of various materials

CO2: Choose and apply appropriate electron microscopy techniques to investigate microstructure of materials at high resolution.

CO3: Apply X-ray diffraction techniques to determine crystal structure of specimen and estimate its crystallite size and stress.

CO4: Select an appropriate spectroscopic technique to analyse the vibrational/ electronic transitions to estimate parameters like energy band gap, elemental concentration, etc.

CO5: Apply thermal analysis techniques to determine thermal stability and thermodynamic transitions of the specimen.

Honors	PRODUCT DESIGN AND DEVELOPMENT (CAD/CAM)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

- To direct the learners to use their creativity, design thinking, and design process to bring new ideas, products, experiences, and value to companies, communities, and people.
- To learn a wide range of hand skills and processes using soft and hard materials, digital design skills in 2-D graphics, and 3-D modelling skills to create well-conceived and executed objects and products that service a human need.

UNIT – 1 **Introduction**: Classification/Specifications of Products, Product life cycle. Product mix, Introduction to product design, Modern product development process, Innovative thinking.

UNIT – 2 **Morphology of design & Conceptual Design**: Generation, selection & embodiment of concept. Product architecture, Industrial design: process, need, Robust Design: Taguchi Designs & DOE, Design Optimization.

UNIT – 3 **Design for Manufacturing & Assembly**: Methods of designing for Manufacturing and assembly, Designs for Maintainability, Designs for Environment, Product costing, Legal factors and social issues, Engineering ethics and issues of society related to design of products. Value Engineering / Value Analysis: Definition. Methodology, Case studies.

UNIT – 4 **Economic Analysis**: Qualitative & Quantitative Ergonomics/Aesthetics, Gross human autonomy, Anthropometry, Man-Machine interaction, Concepts of size and texture, colour. Comfort criteria, Psychological & Physiological considerations.

UNIT – 5 **Creativity Techniques**: Creative thinking, conceptualization, brainstorming, primary design, drawing, simulation, detail design. Concurrent Engineering, Rapid prototyping, Tools for product design – Drafting/Modelling software, CAM Interface, Patents & IP Acts. Overview, Disclosure preparation.

TEXTBOOKS:

1. Karl T Ulrich, Steven D Eppinger , “ Product Design & Development.” Tata McGraw-Hill New Delhi 2003.
2. David G Ullman, “The Mechanical Design Process.” McGraw-Hill Inc Singapore 1992.
3. N J M Roozenberg , J Ekels , N F M Roozenberg “ Product Design Fundamentals and Methods”, John Willey & Sons 1995.

REFERENCE BOOKS:

1. Kevin Otto & Kristin Wood Product Design: “Techniques in Reverse Engineering and New Product Development.” 1/e 2004, Pearson Education New Delhi.
2. L D Miles “Value Engineering.”
3. Hollins B & Pugh S “Successful Product Design.” Butter worths London.
4. Baldwin E N &Neibel B W “Designing for Production.” Edwin Homewood Illinois.
5. Jones J C “Design Methods.” Seeds of Human Futures. John Willey New York.
6. Bralla J G “Handbook of Product Design for Manufacture, McGraw-Hill, New York.

COURSE OUTCOMES: By the end of this course, the student will be able to:

CO1: Apply the product design and development process to manage the development of modern product development process from the new idea.

CO2: Know the principles of product architecture, industrial design and design for manufacturing principles in new product development.

CO3: Learn the principles of product architecture and the importance of DFM, value engineering and Analysis principles for new product development.

CO4: Analyze the qualitative &quantitative economic ergonomics to evaluate the new product development.

CO5: Learn about patenting.

Honors	CAD/CAM LAB (CAD/CAM)	L	T	P	C
		0	0	3	1.5

COURSE OBJECTIVES

- To learn software like Z-Cast Pro, AFDEX and NX-11
- To apply basic concept to drawing and editing to develop 3D Modelling.
- To make 3D modelling, Assembling, modification & manipulation along with detailing.
- To learn and prepare the part programming for the simulation of various machining processes.

CYCLE – I:

Casting and Metal Forming processes:

Simulate and analyses the following processes using a software package.

a) Sand Casting
b) Die Casting
c) Cyclic Casting
d) Two stage Cold Forging
e) Multi-stage Cold Forging
f) Two stage Hot Forging
g) Trimming
h) Piercing
i) Drawing
j) Extrusion

CYCLE – II:

CAM Packages:

a) To write and simulate the plain turning and facing part program for a given component.
b) To write and simulate the taper turning part program for a given component.
c) To write and simulate the step turning part program for a given component.
d) To write and simulate the circular interpolation part program for a given component.
e) To write and simulate the threading part program for a given component.
f) To write and simulate the face milling part program for a given component.
g) To write and simulate the contour milling part program for a given component.
h) To write and simulate the pocket drilling part program for a given component.

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

CO1: Simulate and analyse different Casting processes using a software packages- Z-Cast Pro

CO2: Simulate and analyse different Forging processes using a software package- AFDEX

CO3: Simulate and analyse different Forming processes using a software package- AFDEX

CO4: Write and simulate the manual part programming of lathe, drilling and milling operations using G & M codes- NX11

CO5: Write and simulate the manual part programming drilling and milling operations using G & M codes- NX11

Honors	ROBOTICS AND AUTOMATION LAB (CAD/CAM)	L	T	P	C
		0	0		1.5

COURSE OBJECTIVES

- To develop the student's knowledge in various robot structures and their workspace, skills in performing spatial transformations, analysis skills associated with trajectory planning and robot control.

The following robot programming exercises are to be performed on a robot:

a) Operator control and jogging in the world coordinate system; Jogging in the tool coordinate system
b) Tool calibration – pen; Tool calibration – gripper, 2-point method
c) Jogging in the base coordinate system; Base calibration – table, 3-point method
d) Executing robot programs
e) CP motion and approximate positioning
f) Path contour with spline block
g) Motion programming with spline
h) Gripper programming – plastic panel and Pen
i) Jogging with a fixed tool; Calibrating an external tool and robot-guided work piece
j) Motion programming with external TCP
k) Programming a subprogram call
l) Use of loops, Constant velocity range and conditional stop and Automatic External.
m) Demonstrate the use of a robot for automation of pick and place and arc and spot-welding processes
n) Demonstrate automation of machining processes using a Flexible Manufacturing system

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

CO1: Demonstrate the functional aspects of various subcomponents of robot in the workspace environment.

CO2: Write and simulate trajectory planning in performing various operations like Pick and Place. Loading and unloading, etc.

Honors	ADVANCED HEAT TRANSFER (Thermal Engineering)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. Develop a strong foundation in conduction heat transfer and introduce various methods for mathematical formulation and problem-solving.
2. Provide analytical techniques for solving transient and steady-state heat conduction problems in various geometries.
3. Explore the fundamentals of convection heat transfer, including forced and free convection, with exact and approximate solutions for internal and external flows.
4. Introduce the theory and application of heat exchangers with both LMTD and NTU methods.
5. Impart a comprehensive understanding of radiation heat transfer between surfaces and in enclosures, including radiation in participating media.

UNIT – 1 **INTRODUCTION:** Review of basic concepts of conduction. Method of formulation: lumped, differential and integral formulations. Initial and boundary conditions
TRANSIENT HEAT CONDUCTION: Differential formulation of transient heat conduction problems with time independent boundary conditions in different geometries and their analytical solutions: method of separation of variables, method of Laplace transforms. Differential formulation of steady two-dimensional heat conduction problems in different geometries and their analytical solutions: method of separation of variables, method of superposition.

UNIT – 2 **CONVECTION:** Review of basics concepts and different non-dimensional numbers; Three-dimensional differential energy equation in Cartesian and Cylindrical coordinates.
FORCED CONVECTION: External flow: External laminar forced convection for flow over a semi-infinite flat plate; Integral and similarity solutions for different thermal boundary conditions; Viscous dissipation effects in laminar boundary layer flow over a semi-infinite flat plate.

UNIT – 3 **FORCED CONVECTION: Internal flow:** Internal laminar forced convection: exact solutions to solution for rectilinear flows, axisymmetric rectilinear flows, and axisymmetric torsional flows; Solution for fully developed flow through a pipe with different thermal boundary conditions, Flow in the thermal entrance region of a circular duct: Graetz solution for uniform velocity, Graetz solution for parabolic velocity profile.

UNIT – 4 **FREE CONVECTION:** External laminar free convection: integral and similarity solutions for semi-infinite vertical plate with different thermal boundary conditions
HEAT EXCHANGERS: Classification, LMTD and NTU methods.

UNIT – 5 **RADIATION:** Basic definitions, Radiant energy exchange between two differential area elements. Radiation shape factor: properties and algebra. Radiant energy exchange between two surfaces. Reradiating surfaces. Radiation Shield.
RADIANT ENERGY EXCHANGE IN ENCLOSURES: enclosures composed of black and diffuse-grey surfaces. Electrical network analogy. Radiation in participating media: Radiative heat transfer equation, Radiant energy exchange in presence of absorbing and transmitting media, radiant energy exchange in presence of transmitting, reflecting, and absorbing media.

TEXTBOOKS:

1. Myers, G.E., 1971, Analytical methods in conduction heat transfer, McGraw Hill, New York.
2. Kays, W. M. and Crawford, M. E., 2005, Convective Heat and Mass Transfer, 3rd ed., McGraw Hill.
3. Howell, J.R., Mengüc, M.P., Daun, K., and Siegel, R., 2020, Thermal radiation heat transfer, CRC press, New York.

REFERENCE BOOKS:

1. Arpaci, V.S.,1966, Conduction heat transfer, Addison-Wesley,Reading, Massachusetts.
2. Janna, W.S., 2018, Engineering heat transfer, CRC press, Boca Raton.
3. Fundamentals of Heat and Mass Transfer,5th Ed. / Frank P. Incropera/John Wiley
4. Sparrow, E.M., 2018, Radiation heat transfer, Routledge, New York.
5. Modest, M.F., and Mazumder, S., 2021, Radiative heat transfer, Academic press, New York.
6. Introduction to Heat Transfer/SK Som/PHI
7. Oostuizen, P. H. and Naylor, D., 1999, Introduction to Convective Heat Transfer Analysis, International ed., McGraw Hill.
8. Kakac, S. Yener, Y., and Pramuanjaroenkij. A., 2014, Convective Heat Transfer, 3rd ed., CRC Press

COURSE OUTCOMES: By the end of this course, the student will be able to:

CO1: Formulate and solve heat conduction problems using lumped, differential, and integral approaches with appropriate initial and boundary conditions.

CO2: Analyze and derive analytical solutions for transient and steady-state two-dimensional heat conduction problems using methods like separation of variables and Laplace transforms.

CO3: Apply fundamental principles and governing equations of forced and free convection to analyze thermal behavior in internal and external laminar flows.

CO4: Evaluate heat exchanger performance using both the Log Mean Temperature Difference (LMTD) and the Number of Transfer Units (NTU) methods for various configurations.

CO5: Compute radiant heat exchange between surfaces and within enclosures, using shape factors, network analogies, and radiative heat transfer equations in participating media.

Honors	ADVANCED FLUID MECHANICS (Thermal Engineering)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. Develop a deep understanding of the theoretical foundations of inviscid and incompressible fluid flow, including kinematics and flow descriptions.
2. Introduce the Navier-Stokes equations and provide analytical solutions for fundamental viscous flow problems.
3. Explain boundary layer theory and its practical implications in external flow, including drag prediction and flow separation.
4. Present the fundamentals of turbulence modeling and time-averaged equations, including models for velocity distribution.
5. Provide a rigorous understanding of internal flows and compressible fluid flow phenomena, including shock waves and supersonic aerodynamics.

UNIT – 1 **INVISCID FLOW OF INCOMPRESSIBLE FLUIDS:** Lagrangian and Eulerian descriptions of fluid motion, Path lines, Streamlines, Streak lines, stream tubes – velocity of a fluid particle, types of flows, Equations of three-dimensional continuity equation, Stream and Velocity potential functions, Condition for irrotationality, circulation & vorticity, accelerations in Cartesian systems, normal and tangential accelerations.

UNIT – 2 **VISCOUS FLOW:** Derivation of Navier-Stoke's Equations for viscous compressible flow – Exact solutions to certain cases: Plain Poiseuille flow, Couette flow with and without pressure gradient, Hagen Poiseuille flow.

UNIT – 3 **BOUNDARY LAYER CONCEPTS :** Prandtl's contribution to real fluid flows – Prandtl's boundary layer theory, Boundary layer thicknessfor flow over a flat plate, Blasius solution – Approximate solutions, Von-Karman momentum integral equation for laminar boundary layer — Expressions for local and mean drag coefficients for different velocity profiles.

UNIT – 4 **INTRODUCTION TO TURBULENT FLOW:** Fundamental concept of turbulence – Time Averaged Equations – Boundary Layer Equations, Prandtl Mixing Length Model, Universal Velocity Distribution Law: Van Driest Model, k-epsilon model, boundary layer separation and form drag – Karman Vortex Trail, Boundary layer control, lift on circular cylinders.

INTERNAL FLOW: Smooth and rough boundaries – Equations for Velocity Distribution and frictional Resistance in smooth and rough Pipes – Roughness of Commercial Pipes – Moody's diagram.

UNIT – 5 **COMPRESSIBLE FLUID FLOW:** Thermodynamic basics – Equations of continuity, Momentum and Energy, Acoustic Velocity, Derivation of Equation for Mach Number – Flow Regimes – Mach Angle – Mach Cone – Stagnation State, Area Variation, Property Relationships in terms of Mach number, Nozzles, Diffusers – Fanno and Raleigh Lines– Normal Compressible Shock, Oblique Shock: Expansion and Compressible Shocks – Supersonic Wave Drag.

TEXTBOOKS:

1. L. Victor Steeter, Fluid Mechanics, 10th Edition, Tata McGraw-Hill, 1996.
2. Frank M. White, Fluid Mechanics, 8th Edition, McGraw-Hill Education, 2016.

REFERENCE BOOKS:

1. Modi and Seth, Fluid Mechanics and Machines, Standard Book House
2. Pijush K. Kundu, Ira M. Cohen, and David R. Dowling, Fluid Mechanics, 5th Edition, Elsevier
3. David R. Dowling, Ira M. Cohen, and Pijush K. Kundu, Fluid Mechanics, 5th Edition, Cengage Learning, 2011
4. William S Janna, Fluid Mechanics, CRC Press, 3rd Edition, 2019
5. Y.A Cengel and J.M Cimbala, Fluid Mechanics, MGH, 4th Edition, 2018
6. Schlichting H, Boundary Layer Theory, Springer Publications, 9th Edition, 2017
7. Shapiro, Dynamics & Theory and Dynamics of Compressible Fluid Flow, 2nd Edition
8. William F. Hughes & John A. Brighton, Fluid Dynamics, TMH, 2nd Edition, 2018
9. K.L Kumar, Fluid Mechanics, S Chand & Co., 6th Edition, 2019

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

- **CO1:** Describe fluid motion using both Lagrangian and Eulerian frameworks, and analyze streamlines, pathlines, streaklines, and stream tubes; derive and apply continuity equations for incompressible flows.
- **CO2:** Derive and solve the Navier-Stokes equations for classical viscous flow problems such as Couette and Poiseuille flows in various geometries.
- **CO3:** Apply boundary layer theory, including Blasius and Von Karman solutions, to calculate boundary layer thickness and drag coefficients over flat plates.
- **CO4:** Understand the fundamentals of turbulent flow, apply turbulence models (e.g., mixing length, k-ε model), and analyze boundary layer separation and vortex shedding. And Evaluate internal flows through smooth and rough pipes using velocity distribution equations, friction factors, and interpret results using Moody's diagram.
- **CO5:** Analyze compressible fluid flows using the concepts of Mach number, shock waves, and flow regimes; apply equations for nozzles, diffusers, and flow with area variation (Fanno and Rayleigh lines).

Honors	ADVANCED THERMODYNAMICS & COMBUSTION (Thermal Engineering)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. Provide a comprehensive understanding of availability (exergy), irreversibility, and second-law efficiencies in thermal systems.
2. Develop proficiency in thermodynamic property relations and mathematical formulations involving Maxwell relations, fugacity, and generalized charts.
3. Introduce thermodynamic principles governing gas mixtures and psychrometric processes, with applications to real and ideal gas mixtures.
4. Explore the behavior and equilibrium conditions of real liquid mixtures and the criteria for phase and chemical equilibrium.
5. Apply thermodynamic laws to chemical reactions and combustion processes, including equilibrium constant calculations and adiabatic flame temperature analysis.

UNIT – 1 **AVAILABILITY AND IRREVERSIBILITY:** Quality of Energy, available and unavailable energy, availability, surroundings work, reversible work and irreversibility, availability in a closed system, availability in a SSSF process in an open system, second law efficiencies of processes, second law efficiency of cycles and exergy balance equations.

UNIT – 2 **THERMODYNAMIC PROPERTY RELATIONS:** Helmholtz and Gibbs Functions, two Mathematical Conditions for Exact Differentials, Maxwell Relations, Clapeyron Equation, Relations for Changes in Enthalpy, Internal Energy and Entropy, Specific Heat Relations, Generalized Relations/Charts for Residual Enthalpy and Entropy, Gibbs Function at zero Pressure: A Mathematical Anomaly, Fugacity, Fugacity Coefficient and Residual Gibbs Function, The Joule, Thomson Coefficient and Inversion Curve, Thermodynamic similarity.

UNIT – 3 **GAS MIXTURES:** Mixtures of ideal Gases, Gas-Vapor Mixtures, Application of First Law to Psychometric Processes, Real Gas Mixtures.

THERMODYNAMIC RELATIONS FOR REAL MIXTURES: Partial Properties, Relation for Fugacity and Fugacity Coefficient in Real Gas Mixtures, Relations for Activity and Activity Coefficient in Real Liquid Mixtures/Solutions.

UNIT – 4 **PHASE EQUILIBRIUM: VAPOR LIQUID EQUILIBRIUM OF MIXTURES:** Phase Diagrams for Binary Mixtures, Vapor, Liquid Equilibrium in Ideal Solutions, Criteria for Equilibrium, Criterion for phase Equilibrium, Calculation of Standard State Fugacity of Pure Component, Vapor Liquid Equilibrium at Low to Moderate Pressures, Determination of Constants of Activity Coefficient Equations, Enthalpy Calculations.

UNIT – 5 **CHEMICAL REACTIONS AND COMBUSTION:** Thermochemistry, Measures of Composition in Chemical Reactions, Application of First Law of Thermodynamics to chemical Reactions, the Combustion Process-Standard Heat/Enthalpy of Combustion, Reactions at actual Temperatures, adiabatic Flame Temperature, Entropy Change of Reacting Systems, Application of second Law of Thermodynamics to chemical Reactions, chemical equilibrium-Advancement of Chemical Reactions, Equilibrium Criterion in Chemical Reactions, equilibrium Constant and Law of Mass Action, Equilibrium Constant for Gas Phase Reactions in the standard state.

TEXTBOOKS:

1. P.K.Nag, Basic and Applied Thermodynamics, 2nd Edition, Tata McGraw-Hill, 2019.
2. J.P Holman, Thermodynamics, 10th Edition, McGraw Hill, 2017.
3. CP Arora, Thermodynamics: An Engineering Approach, 5th Edition, McGraw Hill Education (India) Pvt. Limited, 2016.

REFERENCES:

1. Moran, M. J., Shapiro, H. N., Boettner, D. D., and Bailey, M. B., 2018, Fundamentals of Engineering Thermodynamics, 9th ed., Wiley.
2. Cengel, Y. A., 2010, Introduction to Thermodynamics and Heat Transfer, 2nd ed., McGraw-Hill Education.
3. Bejan, A., 2016, Advanced Engineering Thermodynamics, 4th ed., Wiley. 5. Nag, P.K, 2017, Engineering Thermodynamics, 6th ed., McGraw Hill Education.
4. Sonntag, R. E, Borgnakke, C and Wylen, G. J. V., and., 2023, Fundamentals of Classical thermodynamics, 6th ed., Wiley Eastern Ltd.
5. Jones, J. B. and Hawkins, G. A., 1986, Engineering Thermodynamics, John Wiley Sons.

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

CO1: Analyze energy quality and calculate availability, reversible work, and irreversibility for closed and open systems, and determine second law efficiencies of processes and cycles.

CO2: Apply Maxwell relations, Clapeyron equations, and Gibbs and Helmholtz functions to derive property relations and interpret thermodynamic charts and anomalies.

CO3: Evaluate the thermodynamic behavior of ideal and real gas mixtures, perform psychrometric analysis, and apply the first law to mixed systems. And Determine fugacity, activity, and their respective coefficients for real gas and liquid mixtures, and understand partial properties in multicomponent systems.

CO4: Analyze vapor-liquid equilibrium (VLE) for binary mixtures using phase diagrams and apply equilibrium criteria to solve VLE problems at various pressures.

CO5: Apply the first and second laws of thermodynamics to chemical reactions and combustion processes, evaluate enthalpy and entropy changes, and compute equilibrium constants and adiabatic flame temperatures.

Honors	CRYOGENIC ENGINEERING (Thermal Engineering)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. Introduce the fundamental principles of cryogenics and the behavior of fluids and materials at cryogenic temperatures.
2. Explain various gas liquefaction techniques, including the working principles and thermodynamic aspects of each system.
3. Teach the theory and design principles of cryogenic air separation systems using phase equilibrium and thermodynamic laws.
4. Familiarize students with different types of cryogenic refrigeration systems and cryocoolers used in scientific and industrial applications.
5. Provide an understanding of storage, instrumentation, and insulation methods for cryogenic fluids and systems.

UNIT – 1 **FLUID AND MATERIAL PROPERTIES AT LOW TEMPERATURE & APPLICATIONS OF CRYOGENICS:** Introduction to cryogenics: Cryogenic temperature scale, Properties of cryogenic fluids, super fluidity of He3 & He 4, properties of engineering materials at cryogenic temperatures, mechanical properties, thermal properties, electric & magnetic properties, super conducting materials. Applications of cryogenic systems: Super conductive devices, space technology, space simulation, cryogenics in biology and medicine, food preservation and industrial applications, nuclear propulsions, chemical propulsions.

UNIT – 2 **CRYOGENIC GAS LIQUIFICATION:** Gas liquefaction systems: Introduction, thermodynamically ideal systems, Joule Thomson effect, liquefaction systems such as Linde Hampton, precooled Linde Hampson, Linde dual pressure, cascade system, Claude system, Kapitza system, Heyland systems using expanders, comparison of liquefaction systems and its performance evaluations.

UNIT – 3 **CRYOGENIC AIR-SEPARATION:** Basics of Gas Separation, Ideal Gas Separation System, Gibbs Phase Rule, Phase Equilibrium Curves, Temperature Composition Diagrams, Raoult's Law, Gibbs – Dalton's Law, Distribution Coefficient, Enthalpy composition diagrams, Rectification Column Murphree efficiency, Theoretical Plate Calculations.

UNIT – 4 **CRYOGENIC REFRIGERATOR AND CRYOCOOLERS:** Cryogenic Refrigeration System: Ideal isothermal and reversible isobaric source refrigeration cycles, Joule Thomson system, cascade or pre-cooled joule–Thomson refrigeration systems, expansion engine and cold gas refrigeration systems, Sterling refrigerators, Importance of regenerator effectiveness for the Sterling refrigerators, Gifford single volume refrigerator, Gifford double volume refrigerators analysis, Refrigerators using solids as working media: Magnetic cooling, magnetic refrigeration systems, thermal; valves, nuclear demagnetization, dilution refrigerator

UNIT – 5 **CRYOGENIC FLUID STORAGE, INSTRUMENTATION, AND INSULATION:** Dewar vessel for cryogenic fluid storage, Construction, Inner vessel design, outer vessel design, Temperature measurements, pressure measurements, flow measurements, liquid level measurements, fluid quality measurements, Cryogenic insulation – expanded foams, gas filled & fibrous insulation, vacuum insulation, evacuated powder & fibrous insulation, Opacified powder insulation, multilayer insulation, comparison of performance of various insulations.

TEXTBOOKS:

1. Barron, R., 1985, Cryogenic Systems, SI version, Oxford university press.
2. Scott, R. B., 1962, Cryogenic Engineering, D. Van Nostrand Company.

REFERENCES:

1. Timmerhaus, K. D. and Flynn, T. M., 1989, Cryogenic Process Engineering, Plenum Press.
2. Vance, R. W., and Duke, W. M., 1962, Applied Cryogenic Engineering, John Wiley.
3. Sittig, M., 1963, Cryogenics Research and Applications, D. Van Nostrand Company.
4. Hands, B.A., 1986, Cryogenic engineering, Academic press.
5. Flynn, T. M., 2005, Cryogenic Engineering, Marcel Dekker Inc., New York.

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

CO1: Describe the cryogenic temperature scale, properties of cryogenic fluids, and the behavior of materials under cryogenic conditions including superconductivity and superfluidity.

CO2: Analyze and compare different gas liquefaction systems like Linde-Hampson, Claude, and Kapitza systems based on thermodynamic principles and efficiency.

CO3: Apply thermodynamic laws and phase diagrams to evaluate and design cryogenic air-separation systems, including theoretical plate calculations and rectification columns.

CO4: Explain the working of various cryogenic refrigeration and cooling systems such as Joule-Thomson, Sterling, and Gifford-McMahon refrigerators, and understand magnetic and nuclear-based refrigeration techniques.

CO5: Design and evaluate cryogenic fluid storage systems, select appropriate insulation methods, and understand the use of various measurement and instrumentation tools used in cryogenic applications.

Honors	TURBO MACHINES (Thermal Engineering)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. Provide a thorough understanding of the basic principles and classifications of turbomachines along with their thermodynamic and fluid dynamic foundations.
2. Analyze steam nozzles and turbines, including the design aspects and performance considerations of impulse and reaction turbines.
3. Introduce the fundamentals of gas dynamics and apply shock and supersonic flow theories to turbo machines.
4. Develop the ability to analyze and design centrifugal and axial flow compressors using velocity triangles, thermodynamics, and performance metrics.
5. Explore the working, design, and performance analysis of axial flow gas turbines, including cascade theory, blade design, materials, and cooling technologies.

UNIT – 1 **FUNDAMENTALS OF TURBO MACHINES:**
Classification, Application Thermodynamic analysis; Isentropic flow, Energy transfer; Efficiencies; static and Stagnation conditions; continuity equation; Euler's flow through variable cross-sectional area; unsteady flow in turbo machines.

UNIT – 2 **STEAM NOZZLES:** Effect of back – pressure on the analysis; Design of nozzles. Steam Turbines of C & C –D nozzles : Impulse Turbines: work done and velocity triangles; Efficiencies; Constant Reaction Blading; Design of blade passages, angles and height; Secondary flow; leakage losses; Thermodynamic analysis of steam turbines.

UNIT – 3 **GAS DYNAMICS:** Fundamentals thermodynamic concepts; Isentropic conditions; Mach number and Area – Velocity relation; Dynamic pressure; normal shock relations for perfect gas; supersonic flow, oblique shock waves; normal shock recovery; detached shocks; Aero foil theory. Centrifugal Compressor: Types; Velocity triangles and efficiencies; Blade passage design; Diffuser and pressure recovery; slip factor; stanitz and stodolas formulae; Effect of inlet Mach number; Pre-whirl; performance.

UNIT – 4 **AXIAL FLOW COMPRESSORS:** Flow analysis, work and velocity triangles; Efficiencies; Thermodynamic analysis; stage pressure rise; Degree of reaction; stage loading; general design, effect of velocity incidence; performance. Cascade Analysis: Geometry and Terminology; Blade forces, Efficiency; losses; free and forced vortex blades.

UNIT – 5 **AXIAL FLOW GAS TURBINES:** Work done; velocity triangles and efficiencies; thermodynamic flow analysis; degree of reaction; Zweifels relation; Design cascade analysis – Soderberg – Hawthrone – ainley-correlations; secondary flow; Free-vortex blades; Blade angles for variable degree of reaction; Actuator disc theory; stresses in blades; Blade assembling; materials and cooling of blades; performance; Matching of compressor and turbine; off-design performance.

TEXTBOOKS:

1. Shepherd, I. G., Fundamentals of Turbomachinery, 2nd Edition, John Wiley & Sons, 2005.
2. 2. Yahya, S. M., Elements of Gas Dynamics, 2nd Edition, PHI Learning Pvt. Ltd., 2013.

REFERENCES:

1. Fluid Mechanics and Thermodynamics of Turbomachinery, Dixon, S.L, Elsevier, 2014, 7th Edition.
2. Gas Turbine Theory, Sarvanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., Pearson Prentice Hall, 2017, 7th Edition.
3. G. Gopalakrishnan and D. Prithviraj, Practice on Turbomachines, SciTech Publishers, Chennai.

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

- **CO1:** Understand the fundamentals of Turbo machines to evaluate the performance.
- **CO2:** Apply the knowledge in the design of steam nozzles.
- **CO3:** Understand the basics of gas dynamics and centrifugal compressors.
- **CO4:** Apply the knowledge in the design of axial flow compressors.
- **CO5:** Apply the knowledge in the design of axial flow turbines.

Honors	THERMAL MANAGEMENT IN EV BATTERY AND FUEL CELL SYSTEM (Thermal Engineering)	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES

1. Introduce the principles of battery management systems (BMS) including battery types, functionality, and key electrical parameters.
2. Provide in-depth knowledge of lithium-ion battery operations, aging phenomena, thermal management, and protection mechanisms.
3. Familiarize students with various fuel cell technologies, their working principles, types, and thermodynamic behavior.
4. Understand fundamental convective heat transfer concepts and cooling techniques in Battery Thermal Management Systems (BTMS).
5. Explore advanced thermal modeling and simulation of EV battery systems and analyze case studies from electric vehicle (EV) and fuel cell vehicle (FCV) applications.

UNIT – 1 Introduction to battery management systems and devices, fuel Cells & Batteries, Nominal voltage and capacity, Energy and power.

BATTERY CELLS: Electrochemical and lithium-ion cells, Rechargeable cell, Charging and Discharging Process, Overcharge and Undercharge, Lithium-ion aging: Negative electrode, Lithium-ion aging: Positive electrode, Cell Balancing, Temperature Sensing, Current Sensing, BMS Functionality, High-voltage contactor control, Isolation sensing, Thermal control, Protection, Communication Interface, Range estimation, State-of charge estimation.

UNIT – 2 Introduction – working and types of fuel cell – low, medium and high temperature fuel cell, liquid and methanol types, proton exchange membrane fuel cell solid oxide, hydrogen fuel cells – thermodynamics and electrochemical kinetics of fuel cells.

Basic Convective heat transfer and fluid flow, The fundamental of BTMS: Liquid cooling and Air cooling, Thermoelectric cooling, Heat Transfer Fluids in phase change materials, Heat Pipe (HP), Vapor compression, Direct refrigerant cooling Electric Motor Cooling.

UNIT – 3 Heat dissipations dependence on cold plate's channel's pattern, Heat dissipations dependence on the cold plate's number of channels and their shape, Heat dissipations dependence on the placement of the cooling plate.

High temperature batteries for back-up applications, Flow batteries for load levelling and large-scale grid application, Ni-Hydrogen batteries for space and marine applications.

UNIT – 4 PHEV and BEV Battery Systems, Thermal Conductivity Measurements for EV Battery Applications, Battery State Estimation. EV Battery Cooling- challenges and solutions. Heat Exchanger Design and Optimization Model for EV Batteries using PCMs-system set up, selection of PCMs. Chevrolet Volt Model Battery, Thermal Management System - Case study. Modeling Liquid Cooling of a Li-Ion Battery Pack with software-simulation concepts.

UNIT – 5 Fuel cell system-balance of plant-components required. Fuel cell power plant sizing problems-Fuel Cell Electric Vehicle, Fuel economy calculations-Battery EVs Vs Fuel Cell EVs, High pressure hydrogen tank, Boost convertor, NiMH Battery, Internal circulation system, Case studies-Battery and fuel cells, Challenges and Risks.

TEXTBOOKS:

1. Dinçer, I., Hamut, H. S. and Javani, N., Thermal Management of Electric Vehicle Battery Systems, Wiley Network, 2017.
2. Hart A.B. and Womack G.J., "Fuel Cells – Theory and Applications", Chapman and Hall, 1967.

REFERENCES:

1. Andrea, D., Battery Management Systems for Large Lithium-Ion Battery Packs, Artech, 2010.
2. Söffker D., and Moulik, B., Battery Management System for Future Electric, Mdpi AG, 2020.
3. Linden D., and Reddy, T.S., Handbook of Batteries, 3rd Edition, McGraw-Hill, 2002.
4. Kiehne, H.A., Battery Technology Handbook, Marcel Dekker, NYC, 2003.
5. Nazri G.A., and Pistoa G., Lithium Batteries, Science and Technology, Kluwer Academic Publisher, 2003.
6. Husain, I., Electric and Hybrid Vehicles, Design: Fundamentals, 3rd Edition, CRC press, 2021.
7. Jiang, J., and Zhang, C., Fundamentals and Applications of Lithium-Ion Batteries in Electric Drive Vehicles, John Wiley & Sons, 2015.
8. Revankar, S.T., and Majumdar, P., Fuel Cells: Principles, Design, and Analysis, CRC press, 2014.
9. Sammes, N. ed., Fuel Cell Technology: Reaching Towards Commercialization, Springer Science & Business Media, 2006.

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

CO1: Understand the fundamentals of electric vehicles, battery management systems, and fuel cells.

CO2: Apply heat transfer principles to analyze and manage battery systems.

CO3: Understand the critical role of heat transfer in the successful functioning of fuel cells.

CO4: Understand different measurements for Battery Applications.

CO5: Design and implement effective thermal management strategies for modern applications involving batteries and fuel cells.

Honors	DESIGN OF HEAT TRANSFER EQUIPMENT (Thermal Engineering)	L	T	P	C
		3	0	0	3

Course Objectives

1. Provide a comprehensive understanding of various types of heat exchangers and their industrial applications.
2. Introduce fundamental and advanced methods for heat exchanger analysis, including LMTD, ε-NTU, and other analytical techniques.
3. Develop students' skills in the thermal and mechanical design of different types of heat exchangers such as shell-and-tube, plate, and compact types.
4. Explain the principles of heat transfer in condensers, boilers, and the mechanisms of boiling and condensation.
5. Introduce the concept, design, and application of heat pipes in thermal systems, including advanced and cryogenic systems.

UNIT – 1 Classification of heat exchangers and applications, Concept of overall heat transfer coefficient, fouling factor, LMTD, effectiveness, film coefficients for tubes and annuli, equivalent diameter of annuli, caloric temperature, true temperature difference. Regenerators and recuperates. Various methods in use: ε-NTU, P-NTU, MTD methods, ψ-P and P1-P2 methods, Δ-Π Method.

Thermal design of regenerators, compact heat exchangers. Design calculation of double pipe heat exchanger, double pipe exchangers in series-parallel arrangement.

UNIT – 2 Shell and Tube Heat Exchangers-Tube layouts, baffles, classification of shell and tube heat exchangers, TEMA standards. Design calculation of shell and tube heat exchangers-shell side film coefficient, shell-side equivalent diameter, True temperature difference in a 1-2 exchanger, shell and tube sides pressure drops; Performance analysis of 1-2 heat exchangers, flow arrangements for increased heat recovery.

UNIT – 3 **PLATE HEAT EXCHANGERS:** Mechanical features-plate pack and the frame. Plate types; Advantages and performance limits, passes and flow arrangements, Heat transfer and pressure drop calculations. Basics of compact heat exchangers: heat transfer enhancement, plate-fin heat exchangers, tube-fin heat exchangers.

UNIT – 4 **PRINCIPLES OF CONDENSERS AND BOILERS:** Condensers, Types of condensers, Heat transfer fundamentals of condensers, Nusselt theory of laminar film wise condensation; Thermal design of shell and tube condensers, Condensation outside and inside of horizontal tubes, Condensation outside and inside vertical tubes, Empirical correlations;

BOILERS- fundamentals and types of boiling, Various empirical correlations pertaining to flow boiling.

UNIT – 5 **HEAT PIPES**: Types and applications, operating principle, Working fluids, Wick structures, Pressure balance, Effective thermal conductivity of wick structures, Heat pipe limits, Heat pipe design procedure, Nonconventional heat pipes, Micro heat pipes, cryogenic heat pipes, pulsating heat pipes.

TEXTBOOKS:

1. Kern, D.Q., and Kern, D.Q., Process Heat Transfer, McGraw-Hill, 1950.
2. Shah, R.K., and Sekulic, D.P., Fundamentals of Heat Exchanger Design, John Wiley & Sons, 2003.

REFERENCES:

1. Kakac, S., Liu, H., and Pramuanjaroenkij, A., Heat Exchangers: Selection, Rating, and Thermal Design, CRC Press, 2020.
2. Chi, S. W., Heat Pipe Theory and Practice- A Source Book, McGraw-Hill, 1976.
3. Fraas, A. P., Heat Exchanger Design, John Wiley & Sons, 1989.
4. Dunn, P.D., and Reay, D.A., Heat Pipes, Pergamon, 1994.

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

- **CO1** Understand different types of Heat Exchangers, and their applications in the process industry and be able to analyze their thermal performance.
- **CO2** Design various single-phase heat exchangers.
- **CO3** Design various Plate Type Heat Exchangers.
- **CO4** Apply the principles of boiling and condensation in the design of boilers and condensers.
- **CO5** Understand the principles and workings of various types of heat pipes.

Honors	HVAC SYSTEMS (Thermal Engineering)	L	T	P	C
		3	0	0	3

Course Objectives

1. Provide an understanding of the historical development and impact of air conditioning and HVAC systems. And also Introduce the thermodynamic properties of moist air and psychrometric processes, and teach their applications in air conditioning systems.
2. Equip students with knowledge of comfort air conditioning and factors affecting thermal comfort in indoor environments.
3. Explain the heat transfer mechanisms through building structures, including solar radiation, infiltration, and stack effects.
4. Develop skills in ventilation system design and air distribution, with an emphasis on maintaining good indoor air quality.
5. Teach methods for load calculation and the factors influencing cooling and heating requirements in air conditioning systems. And also Introduce heat pump systems, their operation, and applications, focusing on energy efficiency and COP.

UNIT – 1 **INTRODUCTION:** Brief history of air conditioning and impact of air conditioning. HVAC systems and classifications,

PSYCHROMETRY OF AIR CONDITIONING PROCESSES: Thermodynamic properties of moist air, Important Psychrometry properties, Psychrometric chart; Psychrometric process in air conditioning equipment, applied Psychrometry, air conditioning processes, air washers.

UNIT – 2 **COMFORT AIR CONDITIONING:** Thermodynamics of human body, metabolic rate, energy balance and models, thermoregulatory mechanism. Comfort & Comfort chart, Effective temperature, Factors governing optimum effective temperature, Design consideration. Selection of outside and inside design conditions.

UNIT – 3 **HEAT TRANSFER THROUGH BUILDING STRUCTURES:** Solar radiation; basic concepts, sun-earth relationship, different angles, measurement of solar load, Periodic heat transfer through walls and roofs. Empirical methods to calculate heat transfer through walls and roofs using decrement factor and time lag method. Infiltration, stack effect, wind effect. CLTD/ETD method – Use of tables, Numerical and other methods, Heat transfer through fenestration – Governing equations, SHGF/SC/CLF Tables

UNIT – 4 **VENTILATION SYSTEM:** Introduction- Fundamentals of good indoor air quality, need for building ventilation, Types of ventilation system, Air Inlet system. Filters heating & cooling equipment, Fans, Duct design, Grills, Diffusers for distribution of air in the workplace, HVAC interface with fire and gas detection systems - system requirements, devices and their functioning.

UNIT – 5 **LOAD CALCULATIONS:** Types of air-conditioning systems, General consideration, internal heat gains, system heat gain, cooling and heating load estimate.

HEAT PUMPS: General principles, appropriate conditions for using heat pumps, theoretical and practical COP, refrigerants, absorption heat pump, applications of heat pumps; gas driven heat pumps.

TEXT BOOKS:

1. Dossat, Roy J. and Horan, Thomas J., Principles of Refrigeration, 5th Edition, Prentice Hall, 2001.
2. Arora, R.C., Refrigeration & Air Conditioning, PHI, 2010.

REFERENCES:

1. Gosney W.B., Principles of Refrigeration, Cambridge University Press, 1982.
2. Threlkeld, J.L., Thermal Environmental Engineering, Prentice Hall, 1962.

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

- **CO1:** Understand the fundamentals of Psychrometry of Air-conditioning processes.
- **CO2:** Apply human comfort indices and comfort charts to design indoor conditions of HVAC systems.
- **CO3:** Estimate heating and loads for buildings according to ASHRAE procedures and standards.
- **CO4:** Design and evaluate a complete air distribution system including fan, duct, and installation requirements for a typical HVAC system.
- **CO5:** Understand the basic principles and applications of Heat Pumps.

Honors	ADVANCED HEAT TRANSFE LAB (Thermal Engineering)	L	T	P	C
		0	0	3	1.5

COURSE OBJECTIVES

1. To provide hands-on experience in measuring temperature using thermocouples, including fabrication and calibration techniques. And To enable students to experimentally analyze the performance of various heat exchangers and heat transfer systems.
2. To develop a practical understanding of solar energy devices such as solar flat plate collectors and solar stills. And To experimentally investigate the thermal conductivity of various liquids and gases.
3. To study phase change heat transfer phenomena such as condensation and boiling through lab experiments.
4. To perform critical heat flux experiments and understand boiling heat transfer characteristics.
5. To conduct performance testing on thermal systems such as diesel engines and compressors. And To evaluate the performance of vapor compression refrigeration systems and determine their COP.

LIST OF EXPERIMENTS:

1. To fabricate and calibrate a thermocouple and illustrate its use in the temperature measurement.
2. To determine the LMTD, Effectiveness and Heat Transfer rate of a Shell and Tube Heat Exchanger.
3. To determine the Performance of a Solar Flat Plate Collector.
4. To determine the Performance of a Solar Still.
5. To determine the thermal conductivity of liquids and gases.
6. To determine the heat transfer rate in drop and film wise condensation.
7. To determine the critical heat flux of a wire.
8. To conduct the performance test on four stroke variable compression ratio diesel engine.
9. To conduct the performance test on a reciprocating air compressor
10. To determine the coefficient of performance in a Vapour Compression Refrigeration system.

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

CO1 Fabricate, calibrate, and use thermocouples for accurate temperature measurements in thermal systems. And Calculate the LMTD, effectiveness, and heat transfer rate in shell and tube heat exchangers using experimental data.

CO2 Assess the thermal performance of solar flat plate collectors and solar stills under different operating conditions. And Measure and analyze the thermal conductivity of liquids and gases using appropriate experimental setups.

CO3 Differentiate between dropwise and filmwise condensation and quantify the associated heat transfer rates.

CO4 Determine the critical heat flux and understand its importance in boiling heat transfer and system design.

CO5 Perform engine and compressor tests to evaluate thermal and mechanical performance parameters. And Calculate and analyze the coefficient of performance of vapor compression refrigeration systems through experimentation.

Honors	CFD LAB (Thermal Engineering)	L	T	P	C
		0	0	3	1.5

Course Objectives

1. Develop the ability to solve 1-D parabolic equations using explicit (FTCS, DuFort-Frankel) and implicit (Laasonen) numerical methods.
2. Apply numerical techniques to analyze heat transfer in fin problems with insulated and convective boundaries.
3. Implement numerical methods to simulate Couette flow with and without pressure gradients.
4. Solve elliptic equations using iterative methods such as Point Gauss-Seidel and Successive Over Relaxation (SOR), with emphasis on boundary condition handling.
5. Analyze and solve general parabolic heat conduction problems in various geometries.
6. Model and solve linear hyperbolic equations using explicit (Upwind, Lax) and implicit (BTCS, Crank-Nicolson) schemes for wave propagation problems.

Using any Programming Language, code the following methods with an example:

1. Solution of 1-D parabolic equations
   - Explicit (FTCS, DuFort-Frankel)
   - Implicit (Laasonen)
2. Fin problem with insulated and Convective end
3. Couette Problem with and without pressure Gradient
4. Solution of Elliptic Equations
   - With Point Gauss-Seidel method
   - With Point Successive Over Relaxation Method

   ■ Examples: (i) Temperature Distribution over a rectangular plate with different Boundary conditions on the sides.
5. Solution of Parabolic Equations
6. Solution of Linear Hyperbolic Equations.
   - Using upwind and Lax explicit methods
   - Using BTCS and Crank-Nicolson implicit methods

   ■ Examples: Wave propagation at a high altitude

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

CO1 Formulate and solve 1-D unsteady heat conduction problems using both explicit and implicit finite difference schemes.

CO2 Analyze fin-type heat transfer systems with realistic boundary conditions using numerical methods.

CO3 Simulate viscous flow profiles in a Couette system for different pressure gradient scenarios.

CO4 Compute temperature distributions over a 2-D domain by solving elliptic PDEs using Gauss-Seidel and SOR iterative solvers.

CO5 Apply finite difference methods to simulate transient heat conduction problems in engineering systems.

CO6 Implement numerical schemes for hyperbolic PDEs and interpret wave propagation results, including stability and accuracy aspects.

For Minors in “Mechanical Engineering” (Any 5 theory and 2 Labs):

1. Design of Machine Members
2. Theory of Machines
3. Manufacturing Processes
4. CAD/CAM
5. Thermodynamics
6. Thermal Engineering
7. Material Science and metallurgy
8. Operations Research
9. Manufacturing Processes Lab
10. CAD/CAM Lab
11. Thermal Engineering Lab
12. Theory of Machines Lab

Minors	DESIGN OF MACHINE MEMBERS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. Provide an introduction to design of machine elements.
2. Familiarize with fundamental approaches to failure prevention for static and dynamic loading.
3. Explain design procedures to different types of joints.
4. Teach principles of clutches and brakes and design procedures.
5. Instruct different types of bearings and design procedures.

UNIT – 1 Introduction, Design for Static and Dynamic loads

Mechanical Engineering Design: Design process, design considerations, codes and standards of designation of materials, selection of materials.

Design for Static Loads: Modes of failure, design of components subjected to axial, bending, torsional and impact loads. Theories of failure for static loads.

Design for Dynamic Loads: Endurance limit, fatigue strength under axial, bending and torsion, stress concentration, notch sensitivity. Types of fluctuating loads, fatigue design for infinite life. Soderberg, Goodman and modified Goodman criterion for fatigue failure. Fatigue design under combined stresses.

UNIT – 2 Design of Bolted and Welded Joints

Design of Bolted Joints: Threaded fasteners, preload of bolts, various stresses induced in the bolts. Torque requirement for bolt tightening, gasketed joints.

Welded Joints: Strength of lap and butt welds, Joints subjected to bending and torsion.

UNIT – 3 Power transmission shafts and Couplings

Power Transmission Shafts: Design of shafts subjected to bending, torsion and axial loading. Shafts subjected to fluctuating loads using shock factors.

Couplings: Design of flange and bushed pin couplings, universal coupling.

UNIT – 4 Design of Clutches, Brakes and Springs

Friction Clutches: Torque transmitting capacity of disc and centrifugal clutches. Uniform wear theory and uniform pressure theory.

Brakes: Different types of brakes. Concept of self-energizing and self-locking of brake. Band and block brakes, disc brakes.

Springs: Design of helical compression, tension, torsion and leaf springs

UNIT – 5 Design of Bearings and Gears

Design of Sliding Contact Bearings: Lubrication modes, bearing modulus, McKee's equations, design of journal bearing. Bearing Failures.

Design of Rolling Contact Bearings: Static and dynamic load capacity, Stribeck's Equation, equivalent bearing load, load-life relationships, load factor, selection of bearings from manufacturer's catalogue.

Design of Gears: Spur gears, beam strength, Lewis equation, design for dynamic and wear loads.

Note: Design data book is permitted for examination

TEXT BOOKS:

1. R.L. Norton, Machine Design an Integrated approach, 2/e, Pearson Education, 2004.
2. V.B.Bhandari, Design of Machine Elements, 3/e, Tata McGraw Hill, 2010.
3. Dr. N. C. Pandya &Dr. C. S. Shah, Machine design, 17/e, Charotar Publishing House Pvt. Ltd, 2009.

REFERENCES:

1. R.K. Jain, Machine Design, Khanna Publications, 1978.
2. J.E. Shigley, Mechanical Engineering Design, 2/e, Tata McGraw Hill, 1986.
3. M.F.Spotts and T.E.Shoup, Design of Machine Elements, 3/e, Prentice Hall (Pearson Education), 2013.

COURSE OUTCOMES: By the end of this course, the student will be able to:

CO1 Estimate safety factors of machine members subjected to static and dynamic loads.

CO2 Design fasteners subjected to variety of loads.

CO3 Select of standard machine elements such as keys, shafts, couplings, springs and bearings.

CO4 Design clutches brakes and spur gears.

Minors	THEORY OF MACHINES	L	T	P	C
		3	0	0	3

Course objectives:
The students completing this course are expected to understand the nature and role of the kinematics of machinery, mechanisms and machines. The course includes velocity and acceleration diagrams, analysis of mechanisms joints, Cams and their applications. It exposes the students to various kinds of power transmission devices like belt, rope, chain and gear drives and their working principles and their merits and demerits.

UNIT – 1 **MECHANISMS :** Elements or Links Classification Rigid Link, flexible and fluid link Types of kinematic pairs sliding, turning, rolling, screw and spherical pairs lower and higher pairs closed and open pairs constrained motion completely, partially or successfully constrained and incompletely constrained. Grashoff's law, Degree of Freedom, Kutzbach criterian for planar mechanisms, Mechanism and machines classification of machines kinematic chain inversion of mechanism inversions of quadric cycle chain single and double slider crank chains.

UNIT – 2 **LOWER PAIR MECHANISM:** Exact and approximate copiers and generated types Peaucellier, Hart and Scott Russul Grasshopper Watt T. Chebicheff and Robert Mechanisms and straight line motion, Pantograph. Conditions for correct steering Davis Steering gear, Ackermans steering gear - velocity ratio, Hooke's Joint: Single and double Universal coupling application problems.

UNIT – 3 **KINEMATICS:** Velocity and acceleration Motion of a link in machine Determination of Velocity and acceleration diagrams Graphical method Application of relative velocity method four bar chain. Velocity and acceleration analysis of for a given mechanism, Klein's construction, determination of Coriolis component of acceleration.

PLANE MOTION OF BODY: Instantaneous center of rotation, centroids and axodes relative motion between two bodies Three centres in line theorem Graphical determination of instantaneous centre, diagrams for simple mechanisms and determination of angular velocity of points and links.

UNIT – 4 **CAMS:** Definitions of cam and followers their uses Types of followers and cams Terminology Types of follower motion: Uniform velocity, Simple harmonic motion and uniform acceleration and retardation. Maximum velocity and maximum acceleration during outward and return strokes in the above 3 cases. Analysis of motion of followers: Roller follower circular cam with straight, concave and convex flanks.

BELT DRIVES: Introduction, Belt and rope drives, selection of belt drive- types of belt drives, V-belts, materials used for belt and rope drives, velocity ratio of belt drives, slip of belt, creep of belt, tensions for flat belt drive, angle of contact, centrifugal tension, maximum tension of belt, Chains- length, angular speed ratio, classification of chains.

UNIT – 5 **GEARS:** Higher pairs, friction wheels and toothed gears types law of gearing, condition for constant velocity ratio for transmission of motion, Form of teeth: cycloidal and involute profiles. Velocity of sliding phenomena of interferences Methods of interference. Condition for minimum number of teeth to avoid interference, expressions for arc of contact and path of contact Introduction to Helical, Bevel and worm gearing.

GEAR TRAINS: Introduction to gear Trains, Train value, Types Simple and reverted wheel train Epicyclic gear Train. Methods of finding train value or velocity ratio Epicyclic gear trains. Selection of gear box-Differential gear for an automobile.

TEXT BOOKS:

1. Theory of Mechanisms & Machines by Jagadeesh lal, Metropolitan Pvt.Ltd.
2. Theory of Machines by Thomas Bevan/ CBS Publishers

REFERENCES:
1. Theory of Machines S. S Rattan- TMH Publishers
2. Theory of machines and Machinery-Vickers - Oxford .
3. Theory of Mechanisms and machines A.Ghosh & A.K.Malik East West Press Pvt. Ltd.
4. Kinematics and dynamics of Machinery- R.L Norton- TATA McGraw-Hill

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

CO1 Learn about the kinematics of machinery.
CO2 Understand lower pair mechanisms.
CO3 Analyze the motion of a plane mechanism
CO4 Explain Cams and belt drives.
CO5 Select gears for a given applications

Minors	MANUFACTURING PROCESSES	L	T	P	C
		3	0	0	3

Course objectives:

1. To understand the principles of various coating techniques and fabrication methods for MEMS devices
2. To make the students understand the properties, processing and design of ceramic and composite materials
3. To understand the fabrication methods for MEMS devices.
4. To understand the concepts and principles of nano manufacturing methods.
5. To learn various Rapid Prototyping (RP) processes and their applications.

UNIT – 1 **COATING TECHNIQUES:** Scope, Cleaners, Methods of cleaning, Surface coating types, ceramic and organic methods of coating, and economics of coating. Electro forming, Chemical vapor deposition, Physical vapor deposition, thermal spraying, Ion implantation, diffusion coating, Diamond coating and cladding.

UNIT – 2 **PROCESSING OF CERAMICS:** Applications, characteristics, classification, Processing of particulate ceramics, Powder preparations, consolidation, hot compaction, drying, sintering, and finishing of ceramics, Areas of application.

PROCESSING OF COMPOSITES: Composite Layers, Particulate and fiber reinforced composites, Elastomers, Reinforced plastics, MMC, CMC, Polymer matrix composites.

UNIT – 3 **FABRICATION OF MICROELECTRONIC DEVICES**: Crystal growth and wafer preparation, Film Deposition oxidation, lithography, bonding and packaging, reliability and yield, Printed Circuit boards, computer aided design in micro-electronics, surface mount technology, Integrated circuit economics.

UNIT – 4 **NANOMANUFACTURING:** Nanotubes, Nanoparticles, nanowires, Lithography, Electrospinning, mechanical milling, Inert gas condensation, sputtering, laser ablation, Arc discharge, Solgel methods, working, applications, advantages.

UNIT – 5 **RAPID PROTOTYPING:** Working Principles, Methods, Stereo Lithography, Laser Sintering, Fused Deposition Method, Applications and Limitations, Rapid tooling, Techniques of rapid manufacturing.

TEXT BOOKS:

1. Manufacturing Engineering and Technology*I*Kalpakijian / Adisson Wesley, 1995.
2. Process and Materials of Manufacturing / R. A. Lindburg / 1th edition, PHI 1990.

REFERENCES:

1. Microelectronic packaging handbook / Rao. R. Thummala and Eugene, J. Rymaszewski /VanNostrand Renihold.
2. MEMS & Micro Systems Design and manufacture / Tai — Run Hsu / TMGH
3. Advanced Machining Processes / V.K.Jain / Allied Publications.
4. Introduction to Manufacturing Processes / John A Schey*I*Mc Graw Hill.

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

CO1 Understand the working principles of various surface coating methods.
CO2 Discuss novel and promising techniques in the processing of ceramics and composites.
CO3 Select suitable fabrication methods for MEMS components.
CO4 Learn the concepts and principles of nano manufacturing methods.
CO5 Illustrate the working principles of RP and select appropriate RP process for the application.

Minors	CAD/CAM	L	T	P	C
		3	0	0	3

Course objectives:

1. To introduce curve modeling techniques including cubic splines, Bézier curves, and B-spline curves along with their mathematical and geometric properties.
2. To develop an understanding of surface modeling methods used in computer-aided geometric design including various parametric and freeform surfaces.
3. To provide knowledge on solid modeling techniques and CNC tooling systems used in modern manufacturing practices.
4. To explain the concepts, architecture, and integration of Computer Integrated Manufacturing (CIM) and its role in automation and production systems.
5. To explore various Automatic Identification and Data Capture (AIDC) technologies and their applications in smart manufacturing, including current trends like AI, IoT, and digital manufacturing.

UNIT – 1 Cubic splines : Algebraic and geometric forms of cubic spline.
Bezier Curves: Bernstein basis, equations of Bezier curves, properties, derivatives.
B-Spline Curves: B-Spline basis, equations, knot vectors, properties, NURBS

UNIT – 2 **Surface modeling**: Bicubic surfaces, Coon's surfaces, Bezier surfaces, B-Spline surfaces, surfaces of revolutions, Sweep surfaces, ruled surfaces, tabulated cylinder, bilinear surfaces, Gaussian curvature.

UNIT – 3 **Solid Modeling**: Wire frames, Boundary representation, Half space modeling, spatial cell, cell decomposition, CSG.
CNC tooling – cutting tools materials, high speed steel tools, cement carbide tools, ceramic tools, tools magazines, Automatic Tool Changer, modular accessories in CNC,CNC part programming – manual, computer assisted, APT, CAD/CAM programming, CAM software.

UNIT – 4 **CIM** : Introduction to CIM, Data flow in CIM, CIM wheel, Process involved in CIM, Need for CIM, Advantages & disadvantages of CIM, CIM integration, Challenges, Sub systems in CIM, Present Scenario, Future prospects; Production system: automation in production systems, Manual labour in production systems, Automation principles and strategies.

UNIT – 5 Automatic Identification and Data Capture: Introduction, Reasons for AIDC, bar code, RFID and other AIDC technologies, CAQC – Inspection metrology, CMM, Machine Vision, other optical inspection methods, Non optical Non-contact inspection technologies, Material handling and identification, computers in manufacturing industry – current scenario(AI, ML,DL, Digital manufacturing, IOT, Cloud based manufacturing).

TEXT BOOKS:

1. Elements of Computer Graphics by Roger & Adams Tata McGraw Hill.
2. Geometric Modeling by Micheal E. Mortenson, McGraw Hill Publishers.
3. CAD/CAM: Theory and Practice, Ibrahim Zeid, McGraw Hill Publishers.
4. Chang T C and Wysk R A, 1997, Computer Aided Manufacturing, Prentice hall PTR
5. Xu X, 2009, Integrating Advanced computer aided design, manufacturing and numerical control, Information science reference.

REFERENCES:

1. Groover M P, 2007, Automation, Production systems and computer integrated manufacturing, Prentice hall Press
2. Weatherall A, 2013, Computer integrated manufacturing from fundamentals to implementation. Butterworth – Heinemann.
3. Computer Aided Design and Manufacturing, K.Lalit Narayan, K.MallikarjunaRao, MMM Sarcar, PHI Publishers.

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

CO1 Construct and analyze cubic splines using both algebraic and geometric approaches. And Develop Bézier curves using Bernstein basis and apply their properties and derivatives in CAD applications. And also Formulate B-spline curves, understand the role of knot vectors and apply Non-Uniform Rational B-Splines (NURBS) in design.

CO2 Create and manipulate different types of surfaces such as bicubic, Coons, sweep, ruled, and tabulated surfaces using surface modeling techniques. And Evaluate Gaussian curvature for analyzing surface geometry and smoothness in 3D models.

CO3 Demonstrate proficiency in solid modeling using wireframes, boundary representation, CSG, and spatial decomposition. And Identify CNC tooling materials and components and develop CNC part programs using manual and computer-assisted techniques.

CO4 Explain the components, data flow, and challenges of CIM systems and describe their impact on production automation and integration. And Compare automation strategies and evaluate their applicability in various production environments.

CO5 Understand and apply AIDC technologies such as barcodes, RFID, and machine vision in manufacturing systems. And Describe modern inspection techniques, including CMM and non-contact methods, and analyze their integration in CAQC systems. And Evaluate the role of emerging digital technologies such as AI, machine learning, IoT, and cloud computing in the manufacturing sector.

Minors	THERMODYNAMICS	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. To understand the thermodynamic laws and corollaries.
2. To illustrate the concepts of real gas behavior
3. To apply the general concepts of combustion
4. To analyze power cycles
5. To illustrate the working principles of direct energy conversion techniques.

UNIT – 1 **REVIEW OF THERMODYNAMIC LAWS AND COROLLARIES:** Transient flow analysis, Second law thermodynamics, Entropy, Availability and unavailability, Thermodynamic potential. Maxwell relations, Specific heat relations, Mayer's relation. Evaluation of thermodynamic properties of working substance

UNIT – 2 **P.V.T SURFACE:** Equation of state. Real gas behavior, Vander Waal's equation, Generalization compressibility factor. Energy properties of real gases. Vapour pressure, Clausius-Clapeyron equation. Throttling, Joule Thomson coefficient.

UNIT – 3 **COMBUSTION:** Combustion Reactions, Enthalpy of formation. Entropy of formation, Reference levels of tables. Energy of formation, Heat reaction, Adiabatic flame temperature generated product, Enthalpies, Equilibrium. Chemical equilibrium of ideal gases, Effect of non-reacting gases equilibrium in multiple reactions, The vent Hoff’s equation - Gibbs phase rule.

UNIT – 4 **POWER CYCLES:** Review binary vapor cycle, co-generation and combined cycles, Second law analysis of cycles. Refrigeration cycles. Thermodynamics off irreversible processes. Introduction, Phenomenological laws, Onsager Reciprocity relation, Applicability of the Phenomenological relations, Heat flux and entropy production, Thermodynamic phenomena, Thermo electric circuits.

UNIT – 5 **DIRECT ENERGY CONVERSION INTRODUCTION**: Fuel cells, Thermo electric energy, Thermo ionic power generation, Thermodynamic devices magneto hydrodynamic generations, Photovoltaic cells

TEXT BOOKS:

1. Basic and Applied Thermodynamics/ P.K.Nag/ TMH
2. Thermodynamics/Holman/ Mc Graw Hill.

REFERENCES:

1. Engineering Thermodynamics/PL. Dhār / Elsevier
2. Thermodynamics/Sonntag & Van Wylen / John Wiley & Sons
3. Thermodynamics for Engineers/Doolittle-Messe / John Wiley & Sons
4. Irreversible thermodynamics/HR De Groff.
5. Thermal Engineering / Soman / PHI
6. Thermal Engineering / Rathore / TMH
7. Engineering Thermodynamics/Chatopadyaya/

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

CO1 Understand the thermodynamic laws and corollaries.
CO2 Illustrate the concepts of real gas behavior
CO3 Apply the general concepts of combustion reactions and chemical equilibrium of ideal gases.
CO4 Analyze power cycles
CO5 Apply the working principles of direct energy conversion techniques

Minors	THERMAL ENGINEERING	L	T	P	C
		3	0	0	3

Course objectives:

1. To give insight into basic laws of thermodynamics along with the working principles of boilers
2. To impart knowledge about the standard cycles and IC engine parts
3. To make the students learn the working principles of steam nozzles, turbines and compressors
4. To impart the knowledge about the various types of compressors
5. To make the students gain insights about gas turbines, rockets and jet propulsion.

UNIT – 1 **Air standard Cycles:** Otto, diesel and dual cycles, its comparison, Brayton cycle

Actual Cycles and their Analysis: Introduction, Comparison of Air Standard and Actual Cycles, Time Loss Factor, Heat Loss Factor, Exhaust Blowdown-Loss due to Gas exchange process, Volumetric Efficiency. Loss due to Rubbing Friction, Actual and Fuel-Air Cycles of CI Engines.

UNIT – 2 **I.C ENGINES:** Classification - Working principles of SI and CI engines, Valve and Port Timing Diagrams, -Engine systems – Fuel, Carburettor, Fuel Injection System, Ignition, Cooling and Lubrication, principles of supercharging and turbocharging, Measurement, Testing and Performance.

Boilers: Principles of L.P & H.P boilers, mountings and accessories, Draught- induced and forced.

UNIT – 3 **Steam nozzles:** Functions, applications, types, flow through nozzles, condition for maximum discharge, critical pressure ratio, criteria to decide nozzle shape, Wilson line.

Steam turbines: Classification – impulse turbine; velocity diagram, effect of friction, blade or diagram efficiency, De-leval turbine - methods to reduce rotor speed, combined velocity diagram. Reaction turbine: Principle of operation, thermodynamic analysis of a stage, velocity diagram, Parson’s reaction turbine – condition for maximum efficiency.

Steam condensers: Classification, working principles of different types – vacuum efficiency and condenser efficiency.

UNIT – 4 **Compressors:** Classification, positive displacement, and non-positive displacement type, Reciprocating type - Principle, multi-stage compression, Rotary type – Lysholm compressor –principle and efficiency considerations.

Centrifugal Compressors: Principle, velocity and pressure variation, velocity diagrams.

Axial flow Compressors: Principle, pressure rise and efficiency calculations.

UNIT – 5 **Gas Turbines:** Simple gas turbine plant – ideal cycle, components –regeneration, inter cooling and reheating.

Jet Propulsion: Principle, classification, t-s diagram - turbo jet engines –thermodynamic cycle, performance evaluation.

Rockets: Principle, classification, propellant type, thrust, propulsive efficiency, solid and liquid propellant rocket engines.

TEXT BOOKS:

1. Thermal Engineering - Mahesh Rathore- McGraw Hill publishers
2. Heat Engineering /V.P Vasandani and D.S Kumar/Metropolitan Book Company, New Delhi.

REFERENCES:

1. Engineering Thermodynamics, PK Nag, TMH.
2. I.C. Engines - V. Ganesan- Tata McGraw Hill Publishers
3. Thermal Engineering-M.L.Mathur& Mehta/Jain bros. Publishers
4. Thermal Engineering-P.L.Ballaney/ Khanna publishers.
5. Thermal Engineering / RK Rajput/ Lakshmi Publications
6. Thermal Engineering-R.S Khurmi, &J S Gupta/S.Chand.

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

CO1 Explain the basic concepts of thermodynamic laws and boilers.
CO2 Get knowledge about standard cycles and IC Engines.
CO3 Discuss the concepts of steam nozzles and steam turbines and steam condensers.
CO4 Gain knowledge about the concepts of compressors.
CO5 Acquire insights about gas turbines, jet propulsion and rockets.

Minors	MATERIAL SCIENCE AND METALLURGY	L	T	P	C
		3	0	0	3

Course objectives:

1. To provide a fundamental understanding of the structure of metals, metallic bonding, crystal structures, and the significance of grain boundaries and defects in determining material properties.
2. To introduce the principles of alloy formation, types of solid solutions, and interpretation of phase diagrams including binary systems and phase transformations.
3. To impart knowledge on the structure, classification, and properties of ferrous and non-ferrous metals and alloys, including specialized alloys like superalloys.
4. To explain various heat treatment processes and their effects on the microstructure and mechanical properties of alloys.
5. To introduce the principles, processes, and applications of powder metallurgy in modern manufacturing. and To explore the structure, properties, and manufacturing techniques of ceramic and composite materials, including nanomaterials and their engineering applications.

UNIT – 1 Structure of Metals and Constitution of Alloys: Bonds in Solids, Metallic bond, crystallization of metals, Packing Factor – SC, BCC, FCC& HCP-line density, plane density. Grain and grain boundaries, the effect of grain boundaries on the Properties of metal/alloys – determination of grain size. Imperfections – point, line, surface, and volume-Slip and Twinning. Necessity of alloying, types of solid solutions, Hume Rotherys rules, intermediate alloy phases, and electron compounds

Equilibrium Diagrams: Experimental methods of construction of equilibrium diagrams, Isomorphous alloy systems, equilibrium cooling and heating of alloys, Lever rule, coring miscibility gaps, eutectic systems, congruent melting intermediate phases, peritectic reaction. Transformations in the solid state – allotropy, eutectoid, peritectoid reactions, phase rule, the relationship between equilibrium diagrams, and properties of alloys. Study of binary phase diagrams such as Cu-Ni and Fe-Fe3C.

UNIT – 2 Ferrous metals and Alloys: Structure and properties of White Cast iron, Malleable Cast iron, grey cast iron, Spheroidal graphite cast iron, and Alloy cast irons. Classification of steels, structure and properties of plain carbon steels, Low alloy steels, Hadfield manganese steels, tool and die steels.

Non-ferrous Metals and Alloys: Structure and properties of Copper and its alloys, Aluminium and its alloys, Titanium and its alloys, Magnesium, and its alloys, Super alloys.

UNIT – 3 Heat treatment of Alloys: Effect of alloying elements on Fe-Fe3C system, Annealing, normalizing, hardening, TTT diagrams, tempering, hardenability, surface–hardening methods, Age hardening treatment, Cryogenic treatment of alloys.

UNIT – 4 Powder Metallurgy: Basic processes- Methods of producing metal powders- milling atomization Granulation – Reduction - Electrolytic Deposition. Compacting methods – Sintering – Methods of manufacturing sintered parts. Sintering Secondary operations, coining, machining -Factors determining the use of powder metallurgy-Application of this process.

UNIT – 5 Ceramic and composite Materials: Crystalline ceramics, glasses, cermets, abrasive materials, Classification of composites, various methods of component manufacture of composites, particle–reinforced materials, fiber-reinforced materials, metal-ceramic mixtures, metal–matrix composites and C – C composites. Nanomaterials – definition, properties and applications.

TEXT BOOKS:

1. Introduction to Physical Metallurgy - Sidney H. Avener - McGrawHill
2. Essential of Materials science and engineering - Donald R.Askeland - Cengage.

REFERENCES:

1. Material Science and Metallurgy – Dr. V.D.Kodgire.
2. Materials Science and engineering - Callister & Baalasubrahmanyam
3. Material Science for Engineering students – Fischer – Elsevier Publishers
4. Material science and Engineering - V. Rahghavan
5. Introduction to Material Science and Engineering – Yip-Wah Chung CRC Press
6. Material Science and Metallurgy – A V K Suryanarayana – B S Publications
7. Material Science and Metallurgy – U. C. Jindal – Pearson Publications

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

CO1	Understand Metal Crystalline Structures: Learn about the crystal structures of various metals and examine how different alloy systems stabilize phases.
CO2	Study Ferrous and Non-Ferrous Metals: Explore the properties and uses of both ferrous and non-ferrous metals and alloys across different industries.
CO3	Analyze Heat Treatment Effects: Understand how heat treatment and the addition of alloying elements affect the properties of ferrous metals, such as strength and hardness.
CO4	Learn Metal Powder Production: Grasp the techniques used to produce metal powders and understand the applications of powder metallurgy in manufacturing processes.
CO5	Explore Advanced Materials: Gain knowledge about the properties and uses of advanced materials like ceramics and composites, and understand their applications in various industries.

Minors	OPERATIONS RESEARCH	L	T	P	C
		3	0	0	3

COURSE OBJECTIVES:

1. Understand Linear Programming models
2. Learn Transportation and sequencing problems
3. Solve replacement problems and analyze games theory models
4. Understand waiting line and project management problems
5. Learn dynamic programming and simulation.

UNIT – 1 **INTRODUCTION** - definition– characteristics and phases – types of operation research models – applications.

Linear programming: Problem formulation – graphical solution – simplex method – artificial variables techniques -two–phase method, big-M method – duality principle.

UNIT – 2 **TRANSPORTATION PROBLEM:** Formulation – optimal solution, unbalanced transportation problem – degeneracy, assignment problem – formulation – optimal solution - variants of assignment problem- travelling salesman problem.

SEQUENCING – Introduction – flow –shop sequencing – *n* jobs through two machines – *n* jobs through three machines – job shop sequencing – two jobs through 'm' machines.

UNIT – 3 **REPLACEMENT THEORY:** Introduction – replacement of items that deteriorate with time – when money value is not counted and counted – replacement of items that fail completely, group replacement.

GAME THEORY: Introduction – mini. max (max. mini) – criterion and optimal strategy – solution of games with saddle points – rectangular games without saddle points – 2 x 2 games – dominance principle – m x 2 & 2 x n games -graphical method.

UNIT – 4 **WAITING LINES:** Introduction – single channel – poison arrivals – exponential service times – with infinite population and finite population models– multichannel – poison arrivals – exponential service times with infinite population single channel.

PROJECT MANAGEMENT: Basics for construction of network diagram, Program Evaluation and Review Technique (PERT), Critical Path Method (CPM) – PERT Vs. CPM, determination of floats- Project crashing and its procedure.

UNIT – 5 **DYNAMIC PROGRAMMING:** Introduction – Bellman's principle of optimality – applications of dynamic programming-shortest path problem – linear programming problem.

SIMULATION: Definition – types of simulation models – phases of simulation– applications of simulation – inventory and queuing problems – advantages and disadvantages

TEXT BOOKS:

1. Operations Research-An Introduction/Hamdy A Taha/Pearson publishers
2. Operations Research –Theory & publications / S.D.Sharma-Kedarnath/McMillan publishers India Ltd

REFERENCES:

1. Introduction to O.R/Hiller &Libermann/TMH
2. Operations Research /A.M. Natarajan, P. Balasubramani, A. Tamilarasi /Pearson Education.
3. Operations Research: Methods & Problems / Maurice Saseini, ArhurYaspan& Lawrence Friedman/Wiley

4. Operations Research / R.Pannerselvam/ PHI Publications.
5. Operations Research / Wagner/ PHI Publications.
6. Operation Research /J.K.Sharma/Macmillan Publ.
7. Operations Research/ Pai/ Oxford Publications
8. Operations Research/S Kalavathy / Vikas Publishers
9. Operations Research / DS Cheema/University Science Press
10. Operations Research / Ravindran, Philips, Solberg / Wiley publishers

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

CO1 Understand Linear Programming models
CO2 Interpret Transportation and sequencing problems
CO3 Solve replacement problems and analyze queuing models
CO4 Understand game theory and inventory problems
CO5 Interpret dynamic programming and simulation.

Minors	MANUFACTURING PROCESS LAB	L	T	P	C
		0	0	3	1.5

Course Objectives

1. To impart practical knowledge of pattern design and sand casting processes.
2. To familiarize students with welding techniques such as gas cutting, arc welding, TIG/MIG, and resistance spot welding.
3. To introduce molding techniques including injection and blow molding, along with sheet metal operations.
4. To provide exposure to modern and traditional manufacturing techniques including powder metallurgy, brazing, and plastic molding.
5. To develop hands-on skills in various forming, joining, and casting methods used in manufacturing industries.

List of experiments:

1. Design and making ofpattern
   i. Single piece pattern
   ii. Split pattern
2. Sand properties testing
   i. Sieve analysis (dry sand)
   ii. Clay content test
   iii. Moisture content test
   iv. Strength test (Compression test & Shear test)
   v. Permeability test
3. Mould preparation
   i. Straight pipe
   ii. Bent pipe
   iii. Dumble
   iv. Gear blank
4. Gas cutting and welding
5. Manual metal arcwelding
   i. Lapjoint
   ii. Buttjoint
6. Injection Molding
7. Blow Molding
8. Simple models using sheet metal operations
9. Study of deep drawing and extrusion operations
10. Study of Basic powder compaction and sintering
11. Study of TIG/MIG Welding
12. Study of Resistance Spot Welding
13. Study of Brazing and soldering
14. Study of Plastic Moulding Process.

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

- **CO1** Design and fabricate various patterns and prepare molds for basic castings.
- **CO2** Perform and interpret sand testing procedures to evaluate molding sand properties.
- **CO3** Demonstrate competency in basic welding processes and identify suitable joints for various applications.
- **CO4** Understand and perform injection/blow molding and sheet metal operations for manufacturing simple components.
- **CO5** Analyze and understand advanced manufacturing processes such as powder compaction, deep drawing, extrusion, and plastic molding.

Minors	CAD/CAM LAB	L	T	P	C
		0	0	3	1.5

Course Objectives

1. To experiment with trusses and beams to determine stress, deflection, natural frequencies, harmonic analysis, HT analysis and buckling analysis.
2. To demonstrate part programmes using FANUC controller.
3. To generate G-code for automated tool path using CAM software.
4. To demonstrate with rapid prototyping machine and to print simple parts.
5. To experiment with virtual 3D printing simulation using Vlabs.

List of Experiments

1. Determination of deflection and stresses in 2D and 3D trusses and beams.
2. Determination of principal and Von-mises stresses in plane stress, plane strain and axisymmetric components.
3. Determination of stresses in 3D and shell structures (at least one example in each case)
4. Estimation of natural frequencies and mode shapes, harmonic response of 2D beam.
5. Steady state heat transfer analysis of plane and axisymmetric components.
6. Buckling analysis
7. CNC part programming for turned components using FANUC Controller

(i) Plain turning and facing
(ii) Step Turning Operation
(iii) Taper turning

8. CNC programming for milled components using FANUC Controller

(i) Circular interpolation
(ii) End milling
(iii) Pocket milling

9. Automated CNC Tool path and G-Code generation using CAM packages.
10. Study and demonstration of RP machine-creation of simple parts.
11. Virtual 3D Printing Simulation lab using Vlabs.

https://3dp-dei.vlabs.ac.in/List%20of%20experiments.html

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

CO1	Apply finite element analysis (FEA) techniques to determine deflection, stresses, and strain distributions in 2D and 3D structural components such as trusses, beams, and shells.
CO2	Analyze principal and Von Mises stresses in components under plane stress, plane strain, and axisymmetric conditions using computational tools.
CO3	Perform dynamic analysis including natural frequency estimation, mode shapes, and harmonic response of mechanical structures.
CO4	Develop and execute CNC part programs for turning and milling operations using FANUC controllers and CAM software for automated toolpath generation.
CO5	Demonstrate understanding of additive manufacturing technologies through virtual 3D printing simulations and hands-on experimentation with RP machines.

Minors	THERMAL ENGINEERING LAB	L	T	P	C
		0	0	3	1.5

Course Objectives

1. To demonstrate the characteristics of two stroke and four stroke compression and spark ignition engines.
2. To determine flash point, fire point, calorific value of different fuels using various apparatus.
3. To find out engine friction, and conduct load test of petrol and diesel engines.
4. To demonstrate performance test on petrol and diesel engines.
5. To conduct performance test and determine efficiency of air compressor.

List of Experiments:

1. To determine the actual Valve Timing diagram of a four stroke Compression/Spark Ignition Engine.
2. To determine the actual Port Timing diagram of a two stroke Compression/Spark Ignition Engine.
3. Determination of Flash & Fire points of Liquid fuels / Lubricants using (i) Abels Apparatus; (ii) Pensky Martin's apparatus and (iii) Cleveland's apparatus.
4. Determination of Viscosity of Liquid lubricants/Fuels using (i) Saybolt Viscometer and (ii) Redwood Viscometer.
5. Evaluation of engine friction by conducting Morse test on 4-stroke multi cylinder petrol/diesel engine.
6. To perform the Heat Balance Test on Single Cylinder four Stroke Petrol/Diesel Engine.
7. To conduct a load test on a single cylinder Petrol/Diesel engine to study its performance under various loads.
8. To conduct a performance test on a VCR engine, under different compression ratios and determine its heat balance sheet.
9. To conduct a performance test on an air compressor and determine its different efficiencies.
10. Study of boilers with accessories and mountings
11. Experimentation on installation of Solar PV Cells
12. Demonstration of electronic controls in an automobile

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

CO1 Experiment with two stroke and four stroke compression and spark ignition engines for various characteristics.

CO2 Determine flash point, fire point, calorific value of different fuels using various apparatu

CO3 Perform engine friction, heat balance test, load test of petrol and diesel engines.

CO4 Conduct performance test on petrol and diesel engines

CO5 Perform test and determine efficiency of air compressor

Minors	THEORY OF MACHINES LAB	L	T	P	C
		0	0	3	1.5

COURSE OBJECTIVES

1. To introduce students to experimental techniques used to analyze dynamic and kinematic behavior of mechanical systems.
2. To provide practical understanding of governors, gyroscopes, vibrations, and balancing of rotating masses.
3. To enhance knowledge of mechanical advantage, efficiency, and motion transmission through gears, cams, and mechanisms.
4. To develop competency in measuring forces, speeds, friction, and inertia in mechanical systems.
5. To apply theoretical principles to real-world mechanical systems and validate them through experiments.

List of Experiments:

1. To determine whirling speed of shaft theoretically and experimentally.
2. To determine the position of sleeve against controlling force and speed of a Hartnell governor and to plot the characteristic curve of radius of rotation.
3. To analyse the motion of a motorized gyroscope when the couple is applied along its spin axis
4. To determine the frequency of undamped free vibration of an equivalent spring mass system.
5. To determine the frequency of damped force vibration of a spring mass system
6. To study the static and dynamic balancing using rigid blocks.
7. To find the moment of inertia of a flywheel
8. To plot follower displacement vs cam rotation for various Cam Follower systems.
9. To plot slider displacement, velocity and acceleration against crank rotation for single slider crank mechanism/Four bar mechanism
10. To find the coefficient of friction between the belt and pulley.
11. To study simple and compound screw jack and determine the mechanical advantage, velocity ratio, and efficiency
12. To study various types of gears- Spur, Helical, Worm and Bevel Gears

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

CO1 Determine and analyze critical speeds, dynamic balancing, and gyroscopic effects in rotati systems.

CO2 Experimentally evaluate the behavior of governors and spring-mass systems under vario operating conditions.

CO3 Analyze cam-follower and slider-crank mechanisms to obtain displacement, velocity, a acceleration profiles.

CO4 Measure and interpret mechanical parameters such as moment of inertia, coefficient of frictio and system efficiency.

CO5 Identify and understand the function and applications of various gears and mechanical pow transmission components.