यांत्रिक अभियांत्रिकी विभाग
Department of Mechanical Engineering

Semester-Wise Distribution of the Courses

I Semester					
Sl. No.	**Course Code**	**Course Name**	**Type**	**L-T-P**	**Credits**
1.	MA100	Matrices and Advanced Calculus	BS	3-1-0	4
2.	PH100	Engineering Physics	BS	3-0-0	3
3.	CS100	Computer Programming and Problem Solving	ES	3-0-0	3
4.	EE100	Basics of Electrical Engineering	ES	2-0-0	2
5.	ME100	Engineering Mechanics	ES	3-0-0	3
6.	HU100	Liberal Arts	OT	0-0-2	1
7.	PH101	Engineering Physics Lab	BS	0-0-3	2
8.	CS101	Computer Programming Lab	ES	0-0-2	1
9.	EE101	Basics of Electrical Engineering Lab	ES	0-0-3	1*
10.	ME101	Engineering Drawing	ES	1-0-3	3
Total Credits					**23**

II Semester					
Sl. No.	**Course Code**	**Course Name**	**Type**	**L-T-P**	**Credits**
1.	MA150	Differential Equations and Vector Calculus	BS	3-1-0	4
2.	CY150	Engineering Chemistry	BS	3-0-0	3
3.	HU150	Professional Communication	HU	2-0-3	4
4.	EC150	Basics of Electronics Engineering	ES	2-0-0	2
5.	ME150	Basics of Mechanical and Civil Engineering	ES	3-0-0	3
6.	HU151	Health & Happiness	IKS	2-0-0	2
7.	CY151	Engineering Chemistry Lab	BS	0-0-3	2
8.	EC151	Basics of Electronics Engineering Lab	ES	0-0-3	1*
9.	ME151	Workshop Practices	ES	0-0-3	2
10.	PE150	Physical Education	MLC	1-0-2	0#
Total Credits					**23**

: Half-Semester Course, #: Non credit Course

III Semester					
Sl. No.	**Course Code**	**Course Name**	**Type**	**L-T-P**	**Credits**
1	MA200	Advanced Differential Equations and Complex Analysis	BS	3-0-0	3
2	ME200	Mechanics of Solids	DC	3-0-0	3
3	ME201	Materials and Metallurgical Engineering	DC	3-0-0	3
4	ME202	Fluid Mechanics	DC	3-1-0	4
5	ME203	Mechanics of Machinery	DC	3-1-0	4
6	ME204	Engineering Thermodynamics	DC	3-0-0	3
7	ME205	Design Lab-1	DC	0-0-3	2
8	ME206	Machine Drawing and Computer Graphics	DC	0-0-3	2
Total Credit					**24**

IV Semester					
Sl. No.	**Course Code**	**Course Name**	**Type**	**L-T-P**	**Credits**
1	IE250	Innovation & Entrepreneurship	OT	1-0-0	1
2	ME250	Computational Methods in Engineering	DC	2-0-2	3
3	ME251	Design of machine elements – I	DC	3-0-0	3
4	ME252	Manufacturing Technology – I	DC	3-1-0	4
5	ME253	Machine Dynamics and Vibrations	DC	3-0-0	3
6	ME254	Applied Thermodynamics	DC	3-0-0	3

7	ME255	Thermal Lab - I	DC	0-0-3	2
8	ME256	Machine Shop – I	DC	0-0-3	2
9	ME257	Design Lab – II	DC	0-0-3	2
Total Credit					**23**

V Semester

Sl. No.	Course Code	Course Name	Type	L-T-P	Credits
1	ES300	Environmental Studies	MLC	1-0-0	1
2	ME300	Seminar	DC	0-0-2	1
3	ME5XX	Elective-1	DE/OE*	3-0-0	3
4	ME301	Turbomachines	DC	3-0-0	3
5	ME302	Manufacturing Technology - II	DC	3-0-0	3
6	ME303	Heat Transfer	DC	3-1-0	4
7	ME304	Design of machine elements - II	DC	3-1-0	4
8	ME305	Machine Shop - II	DC	0-0-3	2
9	ME306	Thermal Lab - II	DC	0-0-3	2
Total Credit					**23**

VI Semester

Sl. No.	Course Code	Course Name	Type	L-T-P	Credits
1	HU350	Professional Ethics and Human Values	MLC	1-0-0	1
2	IK350	Indian Knowledge System	IKS (OE)		3
3	ME350	Metrology	DC	3-0-0	3
4	ME351	Computer Aided Engineering	DC	3-1-0	4
5	ME352	Industrial Engineering	DC	3-0-0	3
6	ME5XX	Elective-2 (Non-Minor students)	DE	3-0-0	3
7	ME353	Computer Aided Engineering (CAE) Lab	DC	0-0-3	2
8	ME354	Metrology Lab	DC	0-0-3	2
Total Credit					**21**

VII Semester

Sl. No.	Course Code	Course Name	Type	L-T-P	Credits
1	ME400	Summer Project/ Industrial Training	DC	0-0-2	1
2	ME401	Comprehensive Examination	DC	0-0-0	1
3	ME402	Major Project-I	DC	0-0-3	2
4	HS350	Industrial Economics	HU&HS	3-0-0	3
5	ME5XX	Elective-3	DE/OE*	3-0-0	3
6	ME5XX	Elective-4	DE/OE*	3-0-0	3
7	ME5XX	Elective-5	DE/OE*	3-0-0	3
8	ME5XX	Elective-6	DE/OE*	3-0-0	3
Total Credit					**19**

VII Semester

Sl. No.	Course Code	Course Name	Type	L-T-P	Credits
1	ME450	Major Project-II	DC	0-0-6	3
2	ME5XX	Elective-7	DE/OE*	3-0-0	3
3	ME5XX	Elective-8	DE/OE*	3-0-0	3
4	ME5XX	Elective-9	DE/OE*	3-0-0	3
5	ME5XX	Elective-2 (Minor students)##	DE/OE*	3-0-0	3
	Total Credit				**12**

##Total credit for Minor students in VIII semester is 15.

*A student can register only one open elective (OE) per semester and a maximum of two OE in the B.Tech. tenure. This is excluding the Indian Knowledge system (IKS) course offered in 7th semester. Since, IKS is mandatory OE, students are not allowed to register for an OE in that semester.

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III SEMESTER

Sl. No.	Course Code	Course Name	Type	L-T-P	Credits
1	MA200	Advanced Differential Equations and Complex Analysis	BS	3-0-0	3
2	ME200	Mechanics of Solids	DC	3-0-0	3
3	ME201	Materials and Metallurgical Engineering	DC	3-0-0	3
4	ME202	Fluid Mechanics	DC	3-0-0	3
5	ME203	Mechanics of Machinery	DC	3-1-0	4
6	ME204	Engineering Thermodynamics	DC	3-1-0	4
7	ME205	Design Lab-1	DC	0-0-3	2
8	ME206	Machine Drawing and Computer Graphics	DC	0-0-3	2
Total Credit					**24**

Course Code	Course Name	L	T	P	Credits
MA200	Advanced Differential Equations and Complex Analysis	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**

Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
This course is crafted to provide engineers and scientists with a comprehensive grasp of series solutions for both ordinary differential equations and partial differential equations. Further, with a focus on key principles such as complex variables and their practical applications, students will develop a deep understanding of applied mathematics and its real-world implications.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Acquire a solid comprehension of advanced techniques for solving ordinary differential equations (ODEs) and apply them to address challenging engineering problems.
- **CO2.** Comprehend the significance and analytical solving methods for one-dimensional heat and wave equations, as well as two-dimensional elliptic equations.
- **CO3.** Grasp the fundamentals of complex variables, complex functions, and the processes of complex differentiation and integration.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H	H	M	M			L	L	M		H
CO2	H	H	H	H	H			L	L	M		H
CO3	H	H	H	H	H			L	L	M		H

Syllabus

Series Solutions of ODEs: Special Functions: Power series method, Legendre’s equation, Legendre polynomials and its properties, Extended power series method: Frobenius method, Bessel’s equation, Bessel functions and its properties, Bessel functions of the second kind, General solution of Bessel’s equation. Sturm–Liouville Problems, Orthogonal Functions, Orthogonality of Legendre Polynomials, Orthogonal Series, Generalized Fourier Series

Advanced Partial Differential Equations: Vibrating string problem, Fourier series solutions for 1D wave equation, D’Alembert’s solution of the wave equation, Fourier series solutions for 1D heat equation, Steady state 2D heat problems, Laplace equation in polar coordinates.

Complex Analysis: Functions of a complex variable, Analytic functions, Cauchy-Riemann equations, Elementary complex functions, Contours and contour integration, Cauchy’s theorem, Cauchy integral formula; Power Series and properties, Taylor series, Laurent series, Zeros, Singularities, Poles, Essential singularities, Residue theorem, Evaluation of real integrals and improper integrals.

References/Text Materials:

1. E. Kreyszig, "Advanced Engineering Mathematics," 8th ed. John Wiley, 1999.
2. T. Myint-U and L. Debnath, "Linear Partial Differential Equations for Scientists and Engineers," Birkhäuser Boston, MA, 2006.
3. R. V. Churchill and J. W. Brown, "Complex Variables and Applications," 7th ed. McGraw-Hill, 2003.

Course Code	Course Name	L	T	P	Credits
ME200	**Mechanics of Solids**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course objective is to impart a fundamental understanding of the behavior of materials under applied loads and to develop analytical and problem-solving skills for analyzing and designing structures in the field of mechanics of solids.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Define 3D state of stress and strains, equilibrium, stress strain relationships, and compatibility.
- **CO2.** Calculate shear force, bending moment, deflection and slopes in various types of beams for different loading conditions.
- **CO3.** Analyze structures under combined loading conditions.
- **CO4.** Understand and compare various theories of failure, recognizing their limitations in practical applications.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	H							M			
CO3	H	H	H	H					M			
CO4	H	H		M					M			

Syllabus

Introduction: mathematical preliminaries, and notations, the concept of traction vector, concept of the stress tensor, stress-strain diagram, Hooke's law, analysis of composite section, thermal stresses, material constants for isotropic bodies.

Stress tensor: Basics and its representation in Cartesian coordinate system, Transformation of stress matrix, Equations of equilibrium, symmetry of stress tensor.

Principal Stresses and Mohr's Circle: State of stress in simple cases, Principal stress components and principal planes, Maximizing shear component of traction, Mohr's circle, Stress invariants, octahedral plane, Decomposition of stress tensor, concept of strain and stress tensor.

Strains: Longitudinal, shear, and volumetric strains, local infinitesimal rotation, strain compatibility condition.

Constitutive equations of linearly isotropic elastic bodies

Pressure Vessels: Thin and thin pressure vessels. Principal stresses and their planes.

Beam Theory: Shear force diagram and bending moment diagram, stresses in beam: pure bending, bending stresses in symmetrical and non-symmetrical cross-sections, Shear stresses in beams, Euler-Bernoulli beam theory, deflection and slopes of various beams.

Torsion: Derivation of torsion equation with the assumptions made in it, torsional shear stresses, strength and rigidity criteria for the design of shaft, torque transmitted for solid and hollow circular shafts

Column and struts: Failure of long and short columns, slenderness ratio, assumptions made in Euler's column theory, end conditions for the column, Euler's critical load for different end conditions of column.

Combined Loading: Members subjected to combined extension, torsion, and bending.

Energy Methods: strain energy stored in a body when it is subjected to gradually applied load, suddenly applied loads, and impact loads, strain energy stored in bending and torsion. Reciprocal relations, Castigliano's theorem, deflection of straight and curved beams using energy method.

Theories of Failures: Understating, limitations, comparison, and application.

References/Text Material:

1. F. L. Singer, "Strength of Materials," 3rd ed. Harper and Row Publishers, New York, 1980.
2. F. P. Beer, E. R. Johnston, J. T. Dewolf, "Mechanics of Materials," 3rd ed. Tata McGraw Hill, New Delhi, 2007.
3. L. S. Srinath, "Advanced Mechanics of Solids," Tata McGraw Hill Publishing Company Ltd., 2009.
4. S. P. Timoshenko, J. N. Goodier, "Theory of Elasticity," 3rd ed. McGraw Hill Education, 2010.
5. I. Shames, "Introduction to Solid Mechanics," 3rd ed. Prentice Hall of India, 2003.
6. S. M. A. Kazimi, "Solid Mechanics," 1st ed. Tata McGraw Hill Education, 1982.
7. P. N. Singh, P. K. Jha, "Elementary Solid Mechanics," New Age International (P) Ltd., Delhi, 2011.
8. S. Ramamrutham, "Strength of Materials," Dhanpat Rai Publishing Co. (P) Ltd.
9. Prof. Ajeet Kumar, "Solid Mechanics," NPTEL.

Course Code	Course Name	L	T	P	Credits
ME201	Materials and Metallurgical Engineering	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: Assignments, Quizzes, and Written Exams

Course Objective

The objective of the course is to gain a deep understanding of materials engineering, from the atomic level to diverse material types and their applications, including metals, alloys, polymers, ceramics, and composites. It also aims to learn to select, process, and test materials for real-world engineering challenges, considering microstructure, heat treatment, failure mechanisms, and various testing procedures.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Impart knowledge on the atomic arrangement and structure of metals and alloys.
- **CO2.** Construct the phase diagram and using of iron-iron carbide phase diagram for microstructure formation.
- **CO3.** Select and apply various heat treatment processes and its microstructure formation.
- **CO4.** Illustrate the different types of ferrous and non-ferrous alloys and their uses in engineering field.
- **CO5.** Illustrate the different polymer, ceramics and composites and their uses in engineering field.
- **CO6.** Explain the various testing procedures and failure mechanism in engineering field.

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H					M	H	M				H
CO2	H	H	M	L		M						M
CO3	H				M	M	H	M	L			M
CO4	H					M	L	L				M
CO5	H					M		L				M
CO6	H		M		H	M		H	M			M

Syllabus:

Introduction of Materials and Phase Diagrams: Introduction to materials and metallurgical engineering, Metals, Solidification, Constitution of alloys, phase diagrams, Iron – Iron carbide equilibrium diagram. steel and cast-Iron microstructure, properties and application.

Heat Treatment: Various heat treatment processes, Isothermal transformation diagrams, continuous cooling Transformation (CCT) diagram, Hardenability, hardening

Ferrous and Non-Ferrous Metals: Steel, Effect of addition of various alloying elements on steel, Cast Iron, Copper, Aluminium and its alloy, Other important alloys, Properties and Applications, overview of materials standards

Non-metallic Materials: Polymers – types, Properties and applications, Engineering Ceramics – Properties and applications, Composites- Matrix and reinforcement Materials, Types and applications

Mechanical Properties and Deformation Mechanisms: Testing of Engineering materials, Fracture and failure of materials, failure mechanisms

References/Text Materials:

1. K. G. Budinski and M. K. Budinski, "Engineering Materials," 9th ed. Prentice Hall of India Private Limited, 2018.
2. S. H. Avner, "Introduction to Physical Metallurgy," McGraw Hill Book Company, 1994.
3. Alavudeen, N. Venkateshwaran, and J. T. Winowlin Jappes, "A Textbook of Engineering Materials and Metallurgy," Laxmi Publications, 2006.
4. S. Wadhwa and H. S. Dhaliwal, "A Textbook of Engineering Material and Metallurgy," University Sciences Press, 2008.
5. Williams D Callister, “Material Science and Engineering” Wiley India Pvt Ltd, 2nd Ed. Re print 2019.
6. G. S. Upadhyay and A. Upadhyay, "Materials Science and Engineering," Viva Books Pvt. Ltd, New Delhi, 2020.
7. V. Raghavan, "Materials Science and Engineering," 6th ed. Prentice Hall of India Pvt. Ltd., 2019.

Course Code	Course Name	L	T	P	Credits
ME202	**Fluid Mechanics**	**3**	**1**	**0**	**4**

Credit: **4**
Contact hours (L-T-P): **3-1-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to familiarize with the properties of fluids and the applications of fluid mechanics. It also intends to formulate and analyze problems related to the calculation of forces in fluid-structure interaction.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Explain fluid mechanics fundamentals, including concepts of mass and momentum conservation.
- **CO2.** Apply the Bernoulli equation and control volume analysis to solve problems in fluid mechanics.
- **CO3.** Discuss potential flow theory, laminar and turbulent boundary layer fundamentals
- **CO4.** Perform dimensional analysis for problems in fluid mechanics.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	H	H	M					M			
CO3	H								M			
CO4	H	H	H	M					M			

Syllabus

Introduction*:* Properties of fluids, viscosity, capillarity and surface tension, Fluid pressure and its measurement Pressure variation in compressible and incompressible fluids, Hydrostatics: Forces on plane and curved surfaces, Buoyancy, Stability of floating and submerged bodies, Relative equilibrium pressure distribution in liquid subjected to acceleration and rotation.

Flow Kinematics*:* Types of flows; steady and unsteady, rotational and irrotational, laminar and turbulent, etc. Translation of a Fluid Element, Streamlines, potential lines, flow net, vortex motion, Velocity and acceleration at a point, stream function, potential function, continuity equation, Conservation of Momentum: Momentum Theorem, Reynolds Transport Theorem,, Euler's Equation, Conservation of Energy, Steady Flow Energy Equation, Bernoulli's equation and its applications. Dimensional Analysis.

Measurement of Fluid Flow*:* Through ducts: Orifice meter, venturi meter, rotameter, etc., Through open channels: Triangular notch, Rectangular notch, trapezoidal notch, etc., Through reservoirs: Orifice, mouthpiece, etc.

Viscous Flow*:* Through pipes and parallel plates (Hagen poiseuille and plane poiseuille flow)

Boundary layer concept, boundary layer thickness, wall shear, displacement thickness, momentum thickness and energy thickness, integral equation, Boundary layer separation, Flow around immersed bodies.

Flow Through Pipes*:* Major and minor losses, friction chart, Pipes in series and parallel, Siphon, Power transmission, Hydraulic Gradient Line and Total Energy Line

Compressible Flows*:* Introduction to compressible flows, speed of sound wave, Mach number, Mach cone, one dimensional isentropic flows, stagnation properties, flow through nozzles, normal shock

References/Text Material:

1. S. K. Som, G. Biswas, and S. Chakraborty, "Introduction to Fluid Mechanics and Fluid Machines," 3rd ed. McGraw Hill Education, 2017.
2. F. M. White and H. Xue, "Fluid Mechanics," Standard ed. McGraw Hill, 2022.
3. Y. A. Cengel and J. M. Cimbala, "Fluid Mechanics: Fundamental and Applications," 3rd ed. McGraw Hill Education, 2017.
4. R. K. Bansal, "A Textbook of Fluid Mechanics and Hydraulic Machines," 10th ed. Laxmi Publications, 2019.
   B. R. Munson, A. P. Rothmayer, T. H. Okiishi, and W. W. Huebsch, "Fundamentals of Fluid Mechanics," 7th ed. Wiley, 2017.

Course Code	Course Name	L	T	P	Credits
ME203	Mechanics of Machinery	3	1	0	4

Credit:	**4**
Contact Hours (L-T-P):	**3-1-0**
Overlaps with:	**Nil**
Couse Assessment Method:	**Tutorials, Quizzes, DIY Projects, and Written Exams**

Course Objective

The aim of the course is to equip students with the expertise to analyze and design mechanical systems. By delving into kinematics, motion analysis, mechanism synthesis, cams, gears, and force analysis, the course fosters essential skills for engineering applications and machinery design.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand of the fundamental concepts and principles of kinematics and dynamics of mechanisms, including the classification of links, pairs, and mobility.
- **CO2.** Perform graphical and analytical analysis of position, velocity, and acceleration of planar mechanisms.
- **CO3.** Synthesize planar mechanisms using graphical and analytical techniques, as well as computer-aided methods.
- **CO4.** Discuss the design and analysis of cams, gears, and gear trains, including their classification and terminology.
- **CO5.** Discuss static and dynamic force analysis principles and apply them to analyze four-bar and slider-crank mechanisms.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	M										
CO2		H	M	H								
CO3		H	H	H					M	L		
CO4		H	H	H					M	L		
CO5		H	H	M					M	L		

Syllabus

Introduction: Introduction to kinematics of mechanisms - perspective on kinematics and kinetics, machine and mechanism. Kinematics fundamentals - mobility, classification of links, pairs, Number Synthesis, Planar mechanism and machines - Four-bar, and slider-crank linkage, inversions of mechanisms along with their practical applications.

Position and Motion Analysis of Mechanisms: Graphical and analytical position, velocity and acceleration analysis of planar mechanisms, Instantaneous center method, Coriolis acceleration, Klein's construction, Computer-aided analysis.

Motion synthesis: Introduction to synthesis of mechanisms, Graphical methods of synthesis, Chebyshev spacing, two position synthesis, application to four bar mechanism, analytical synthesis using complex algebra, Freudenstein's method, Computer-aided synthesis.

Cams: Classification of different types of cams, types of motion curves and their analytical expressions, graphical construction of cam profiles for different types of followers, pressure angle and cams with specified contours.

Gears: Classification and Basic terminology, Fundamental law of gearing, Tooth profiles, Types of gears, Gear trains.

Static and Dynamic Force Analysis of Mechanisms: Review of basic principles of statics, Concept of free body and its equilibrium, Static force analysis of planar mechanism, D'Alembert's principle, dynamic force analysis of four-bar and slider crank mechanisms.

References/Text Material:

1. R. L. Norton, "Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines," 6th ed. McGraw Hill, 2020.
2. S. S. Rattan, "Theory of Machines," 4th ed. McGraw Hill, 2017.
3. J. J. Uicker Jr., G. R. Pennock, and J. E. Shigley, "Theory of Machines and Mechanisms," 5th ed. Oxford University Press, 2021.
4. N. Sclater and N. P. Chironis, "Mechanisms and Mechanical Devices Sourcebook," 5th ed. McGraw Hill, 2020.
5. J. Hannah and R. C. Stephens, "Mechanics of Machines," Viva Books Pvt Ltd, 2016.
6. W. L. Cleghorn and N. Dechev, "Mechanics of Machines," 2nd ed. Oxford University Press, 2018.
7. A. Ghosh and A. K. Mallik, "Theory of Mechanics and Machines," East West Pub., 2008.

Course Code	Course Name	L	T	P	Credits
ME204	Basic Thermodynamics	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
The objective of the course is to introduce and apply the laws of thermodynamics to various thermodynamic systems. The course also intends to introduce the topic of entropy and exergy analyses.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Explain the basic thermodynamic entities like laws, properties, systems.
- **CO2.** Apply the first and second law of thermodynamics to closed and open systems
- **CO3.** Analyze gas mixtures using diagrams and tables, understanding ideal and real gases.
- **CO4.** Conduct exergy analysis, applying the Second Law for efficient energy utilization.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								L			
CO2		H	H						H			
CO3		H							H			
CO4		H	M	L					M			

Syllabus

Introduction and Fundamental Concepts: Application Areas of Thermodynamics, Systems and Control Volumes, Properties of a System, State and Equilibrium, Processes and Cycles, Temperature and the Zeroth Law of Thermodynamics, Pressure

Work and Heat Transfer: Definition of Thermodynamic Work, Forms of Work, Definition of Heat, Inter Convertibility of Heat/work into Work/heat, Governing Principles, Sign Convention.

First Law of Thermodynamics: Energy, Enthalpy, Specific heats, First law applied to systems and control volumes, steady and unsteady flow analysis.

Second Law of Thermodynamics: Kelvin-Planck and Clausius statements, reversible and irreversible processes, Carnot theorems, Reversible and Irreversible Engines and processes, Causes of Irreversibility, Internal and External Irreversibility

Entropy and Exergy: Clausius Theorem and Clausius Inequality, The Entropy of A Pure Substance, Entropy Change in Irreversible Process, Principle of Increase of Entropy, Calculation of Change in Entropy, Basic concepts of exergy and irreversibility, exergy for closed system and control volume, exegetic efficiency.

Properties of Pure Substances: Thermodynamic properties of pure substances in solid, liquid and vapor phases, P-V-T behaviour of simple compressible substances, phase rule, thermodynamic property tables and charts, ideal and real gases, equations of state.

Thermodynamic Relations: T-ds relations, Maxwell equations, Joule-Thomson coefficient, coefficient of volume expansion, adiabatic and isothermal compressibilities, Clapeyron equation.

Reference Books/Material

1. Y. A. Cengel and M. A. Boles, "Thermodynamics: An Engineering Approach," 5th ed. McGraw Hill, 2006.
2. R. E. Sonntag, C. Borgnakke, and G. J. Van Wylen, "Fundamentals of Thermodynamics," 6th ed. John Wiley, 2003.
3. P. K. Nag, "Engineering Thermodynamics," 3rd ed. Tata McGraw Hill, 2005.
4. H. N. Shapiro and M. J. Moran, "Fundamentals of Engineering Thermodynamics," 8th ed. Wiley, 2014.
5. Dincer and M. A. Rosen, "Exergy: Energy, Environment and Sustainable Development," 3rd ed. Elsevier, 2020.

Course Code	Course Name	L	T	P	Credits
ME205	**Machine Drawing and Computer Graphics**	**0**	**0**	**3**	**2**

Credit: **2**
Contact hours (L-T-P): **0-0-3**

Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
To equip students with the skills to create assembly drawings for various machine sub-assemblies and assemblies using drafting software.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Demonstrate proficiency in utilizing commercial drafting software for machine drawing
- **CO2.** Conversion of pictorial views into orthographic projections and vice versa
- **CO3.** Gain competence in designing and detailing detachable fasteners
- **CO4.** Acquire skills in creating comprehensive assembly drawings for machine sub-assemblies and assemblies

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H	H		H				L			
CO2	H	H	H		H				H			
CO3	H	H	H		H				H			
CO4	H	H	H	H	H				M			

Syllabus

Introduction to machine drawing: Introduction to commercial drafting software available in the institute, principles of orthographic projections applied to machine drawing: first angle and third angle projections, sectional views, conversion of pictorial projections into orthographic projections, limits, fits, tolerances, surface quality symbols.

Detachable fasteners: Screw threads, approximate and conventional representations, bolts and nuts, specifications, locking arrangements for nuts, studs, screws, washers, pins, foundation bolts, keys, cotter joints, shaft couplings.

Permanent fasteners: Rivets, types of riveted joints, welds, types of welded joints, edge preparation, specifications and representation of welds on drawings.

Assembly drawings: Parts list, numbering of components and associated detail drawings, assembly drawings of various machine sub-assemblies and assemblies from detail drawings (for example: screw jack, connecting rod, square tool post, tailstock, etc.)

Practical sessions using Drafting Software to produce part and assembly drawings

References/Text Material:

1. N. D. Bhatt and V. M. Panchal, "Machine Drawing," Charotar Publishing House, 1991.
2. K. L. Narayana, P. Kannaiah, K. Venkat Reddy, "Machine Drawing," 3rd ed. New Age International Ltd, 2006.
3. K. R. Gopalkrishna, "Machine Drawing," Subhas Publications, 1985.
4. N. D. Junnarkar, "Machine Drawing," Pearson Education India, 2007.
5. G. Pohit, "Machine Drawing with AutoCAD," Pearson Education India, 2004.

Course Code	Course Name	L	T	P	Credits
ME206	**Design Laboratory – I**	**0**	**0**	**3**	**2**

Credit: **2**
Contact hours (L-T-P): **0-0-3**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

This laboratory course aims to complement theoretical understanding with hands-on experience, enabling students to apply and experimentally validate principles of mechanics of solids, material properties, and mechanics of machine elements through demonstration, laboratory exercises and material testing.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to –

CO1. Supplement the theoretical knowledge gained in Mechanics of Solids with practical testing for determining the strength of materials under externally applied loads.

CO2. Characterize materials and have hands on experience in using different experimental setups.

CO3. Implement various linkages and drives in dynamic systems for diverse needs.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H	M	M				M	H	H		M
CO2	H	H	M	M	M			M	H	H		M
CO3	H	H	M	M				M	H	H		M

List of Experiments

1. Tension tests on mild steel and cast iron
2. Compression tests on mild steel and cast iron
3. Direct Shear tests on mild steel rod, timber specimen, and mild steel plate
4. Bending test on mild steel
5. Torsion test on mild steel
6. Brinell Hardness test, Rockwell Hardness test, Vickers Hardness test
7. Impact test – Charpy and Izod
8. Demonstration on fatigue test and springs.
9. To study creep behavior of a given specimen
10. Analysis of various mechanism- slider-crank mechanism, Cam, etc
11. Experiment using Gyroscope
12. Demonstration of various mechanisms like straight line mechanisms, etc. and gear drives and gear trains thorough prototypes and lab models.
13. Sample preparation and microstructure analysis of polished surface of various metals and alloys using optical microscope.

References/Text Material:

1. E. J. Hearn, "Mechanics of Materials," Pergamon Press, England, 1972.
2. E. R. Beer and E. R. Johnston, "Mechanics of Materials," 3rd ed. Tata McGraw Hill, New Delhi, 2007.
3. R. L. Norton, "Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines," 6th ed. McGraw Hill, 2020.
4. S. S. Rattan, "Theory of Machines," 4th ed. McGraw Hill, 2017.

IV SEMESTER

Sl. No.	Course Code	Course Name	Type	L-T-P	Credits
1	IE250	Innovation & Entrepreneurship	OT	1-0-0	1
2	ME250	Computational Methods in Engineering	DC	2-0-2	3
3	ME251	Design of machine elements – I	DC	3-0-0	3
4	ME252	Manufacturing Technology – I	DC	3-1-0	4
5	ME253	Machine Dynamics and Vibrations	DC	3-0-0	3
6	ME254	Applied Thermodynamics	DC	3-0-0	3
7	ME255	Thermal Lab - I	DC	0-0-3	2
8	ME256	Machine Shop – I	DC	0-0-3	2
9	ME257	Design Lab – II	DC	0-0-3	2
Total Credit					**23**

Course Code	Course Name	L	T	P	Credits
IE250	Innovation and Entrepreneurship	1	0	0	1

Course Objective

1. To introduce to a project-based learning approach from Ideation to Innovation and Entrepreneurship will be the key process considered here.
2. To learn the essential concepts of innovation and entrepreneurship through hands-on activities and the best and most relevant practical examples.
3. To provide the tools necessary for starting independent innovation and businesses.
4. To give students practical experience in market survey, commercialization, IPR and proactively work in projects in risky market environments

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability

CO1. To comprehend the basic theories and concepts that underlie a survey study of Innovation, Entrepreneurship and Social Business/ Entrepreneurship

CO2. To understand how to generate good large company or startup business ideas / societal ideas, and refine these ideas, to substantially increase chances for success in the marketplace

CO3. The students will be exposed to the thoughts and strategies of some very effective real-life innovators and entrepreneurs through videos and small cases.

CO4. To understand about IPR, prototyping and financial management.

Relationship of Course Outcomes to Program Outcomes

H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	L	H	L	H	M	H	H	L	H	H	H	H
CO2	L	H	L	H	H	H	H	L	H	H	H	H
CO3	L	H	L	H	H	H	H	L	M	H	H	H
CO4	L	H	L	H	H	H	H	H	L	L	H	H

Syllabus

Module 1: Introduction

Creative thinking, blocks to creativity, factors that influence creative design, engineering design and creative design, influence of society, market pull & technology push, attribute of a creative person Three levels of Design – Viceral, Behavioral and Reflective design. Qualities and skills required for entrepreneurship, Functions of an entrepreneur, Importance of entrepreneur in economic development.

Module 2: Ideas for Entrepreneurship

Need or identification of a problem, market survey, data collection, review & analysis, problem definition, challenge statement, problem statement initial specifications, Brain storming, analogy technique or Synectic, check list, trigger words, morphological method, interaction matrix method, analysis of interconnected decision making.

Module 3: Theory of Inventive Problem Solving (TRIZ)
20 key TRIZ principles – multifunction, compensation, nested doll, blessing in disguise, segmentation, separation, symmetry change, opaque & porous, inflate and deflate, recycle & recover, phase transformation, energy, imaging, environment, composition, economical, surface response, static & dynamic, continuous & intermittent, dimensions.

Module 4: Product Design, IPR & Finance
Detail design, prototyping, product deployment, useful life assessment and recycling and sustainability; patent act, patent la
ws, Types of entrepreneurs- Based on type of business, based on use of technology, based on motivation, based on stages of development, based on motive, Based on capital ownership, Business Plan, Finance and Funding.

Reference Books/Material

1. C.B.Gupta & N.P.Srinivasan, 'Entrepreneurial Development', Sultan Chand & Sons, 2020, ISBN: 978-93-5161-132-5
2. Floyd Hurt, Rousing Creativity: Think New Now, Crisp Publ Inc. 1999, ISBN 1560525479.
3. Kalevi Rantanen & Ellen Domb, 'Simplified TRIZ' – II edn., Auerbach Publications, Taylor & Francis Group, 2010, ISBN: 978-142-0062-748
4. John Adair, 'The Art of Creative Thinking', Kogan Page Publication, 2011, ISBN 978-0-7494-5483-8

Course Code	Course Name	L	T	P	Credits
ME250	Computational Methods in Engineering	2	0	2	3

Credit: **3**
Contact hours (L-T-P): **2-0-2**

Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
This course is designed to offer engineers and scientists a thorough understanding of numerical methods. It emphasizes essential concepts, including numerical solutions for algebraic, transcendental, and differential equations, and explores their practical applications.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Gain expertise in numerical solving techniques for single-variable equations and systems of equations, and then apply these principles to address intricate engineering challenges.
- **CO2.** Understanding of the significance of curve fitting, interpolation, numerical differentiation and integration.
- **CO3.** Foster a deep comprehension of the importance of numerically solving ordinary and partial differential equations (ODEs) and explore their wide-ranging applications across diverse fields.
- **CO4.** Develop a profound understanding of the significance of employing numerical methods through the utilization of diverse programming languages.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H	H	M	M			L	L	M		H
CO2	H	H	H	H	H			L	L	M		H
CO3	H	H	H	H	H			L	L	M		H
CO4	H	H	H	H	H			L	L	M		H

Syllabus

Lectures (28 hours):

Numerical solution of equations and systems: Equations in one variable - The Bisection method, Fixed point iteration method, Secant method, Regular-Falsi method, Newton's method and its extensions, Convergence of Newtons's method. System of equations - Jacobi and Gauss-Seidel iterative methods, Sufficient conditions for convergence, Power method to find the dominant Eigen value and eigenvector.

Interpolation, Numerical Differentiation and Integration: Interpolation and Curve fitting - The Lagrange polynomial, Divided differnces, Method of least square approximations;

Numerical differentiation - Difference formula, Three and five point formule; Numerical integration - Open and closed Newton-Cotes formulae, Gaussian quadrature formula.

Numerical solution of ordinary differential equations: Euler's method, Euler's modified method, Taylor's method and Runge-Kutta method, Multistep methods. Elliptic partial differential equations - Fine difference method for two dimensional equations. Parabolic partial differential equations - Forward difference method, backward difference method and the Crank-Nicolson method for one dimensional equations. Hyperbolic partial differential equations - Central difference method for one dimensional equations.

Laboratory Experiments: (14 hours)

1. Basic operations on Matlab/Python.
2. Program to solve one variable equation using Bisection and Fixed point method.
3. Program to solve one variable equation using Newton Raphson, Regula-Falsi and Secant method.
4. Program to solve system of equations using Gauss-Jacobi Method
5. Program to solve system of equations using Gauss-Seidal Method
6. Program to find dominant eigenvalue using the Power Method
7. Program to fit a curve using method of least square.
8. Program to interpolate using the Lagrange polynomial method.
9. Program to evaluate differentiation and integration.
10. Programs to solve ordinary differential equations using Euler’s and Taylor's method.
11. Programs to solve ordinary differential equations using R-K method of order four.
12. Programs to solve ordinary differential equations using multistep methods.
13. Programs to solve elliptic equations using the finite difference method.
14. Programs to solve parabolic equations using the finite difference method.
15. Programs to solve hyperbolic equations using the finite difference method.

References/Text Material:

1. M. K. Jain, S. R. K. Iyengar, and R. K. Jain, "Numerical Methods for Scientific and Engineering Computation," 6th ed. New Age Publishers, 2012.
2. E. Kreyszig, "Advanced Engineering Mathematics," 8th ed. Wiley India Pvt. Ltd., 2010.
3. R. L. Burden and J. D. Faires, "Numerical Analysis," 9th ed. Brooks/Cole, 2012.
4. G. D. Smith, "Numerical Solution of Partial Differential Equations," Oxford University Press.

Course Code	Course Name	L	T	P	Credits
ME251	**Design of Machine Elements - I**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **Tutorials, Quizzes, Projects, and Written Exams**

Course Objective

The aim of the course is to empower students with a thorough understanding of basics of machine design. Covering design procedures, force analysis, material selection, failure theories, and dynamic loading considerations, the course emphasizes on the fundamental understanding of underlying principles that becomes the basis of designing various machine elements like keys, fasteners, gears, shafts, etc.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the design process, requirements, and force analysis concepts. Apply appropriate material selection methodologies for design applications.
- **CO2.** Analyze various failure modes, mitigate stress concentration, and ensure the reliability of machine designs.
- **CO3.** Comprehend the principles of dynamic loading and consider fatigue aspects for machine elements.
- **CO4.** Design and analyze an initial range of machine elements, including levers, shafts and keys, along with flexible drives.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H						M					
CO2	H	H	H	H								H
CO3	M	H	H	H								H
CO4	M	H	H	H		M	M	H	H	M	M	H

Syllabus

Introduction to Mechanical Engineering Design: Introduction to design procedure; design requirements; standards and codes; preferred sizes; discussion on materials, properties and processes from design perspective.

Static Failure Theories: Types of failures; theories of failures for ductile and brittle materials; factor of safety concepts, applications.

Fatigue Failure Theories: Stress concentration; stress concentration factors; mitigation of stress concentration, cyclic loading, endurance limit, effects of type of loading, size and surface finish; notch sensitivity; reliability considerations; Goodman and Soderberg diagrams; cumulative fatigue damage.

Design of Machine Elements: Design of levers, shafts, and keys, belt and chain drives.

References/Text Material:

1. R. L. Norton, "Machine Design – An Integrated Approach," 6th ed. Pearson Education, 2019.
2. R. G. Budynas and J. K. Nisbett, "Shigley's Mechanical Engineering Design," 10th ed. McGraw Hill, 2014.
3. V. B. Bhandari, "Design of Machine Elements," 5th ed. McGraw Hill, 2020.
4. K. Achhangham, "Design Data: Data Book of Engineers," PSG Tech, 2020.
5. R. C. Juvinall and K. M. Marshek, "Fundamentals of Machine Component Design," 7th ed. Wiley, 2020.
6. K. Mahadevan and K. B. Reddy, "Design Data Handbook for Mechanical Engineering," 4th ed. CBS Publishers, 2019.
7. V. B. Bhandari, "Machine Design Data Book," 2nd ed. McGraw Hill, 2019.

Course Code	Course Name	L	T	P	Credits
ME252	Manufacturing Technology – I	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

This course delves into metal shaping and joining, equipping students with manufacturing production techniques for casting, forming, and assembling metal components to craft functional and artistic creations. From understanding molten metal behavior to welding practices, the course aims to develop versatile skills to manipulate and connect metals with precision and purpose.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the casting processes, including pattern making, moulding, gating systems, solidification, and casting defects.
- **CO2.** Discuss metalworking techniques, such as rolling, spinning, drawing, extrusion, forging, and surface coating.
- **CO3.** Develop skills in sheet metal working operations, including piercing, blanking, forming, drawing, and spinning.
- **CO4.** Gain knowledge of powder metallurgy, including metal powder production, compaction, sintering, and plastics processing.
- **CO5.** Elucidate metal joining techniques, including welding, soldering, brazing, and the use of mechanical fasteners

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	M		L					M			
CO3	H	M		L					M			
CO4	H			L					M			
CO5	H	M		L					M			

Syllabus

Introduction: Introduction to manufacturing processes, Types and need for manufacturing

Pattern Making: Casting Processes, Pattern, Moulding sand, Moulds, cores

Casting: Gating system, Solidification mechanisms, Melting Furnaces and melting practices, Casting Defects and Remedies. Special casting processes, Advantages and limitations of casting processes, selection, inspection and testing of casting process

Mechanical Working of Metals: Hot rolling, hot spinning, wire drawing. Metal Forming Processes, Extrusion Process, Punches and dies, sheet metal working operations

Forging Processes: Forging materials, classification of forging operations, types of forging operations. defects in forging, Rotary swaging.

Metal joining: welding processes, Arc welding, Resistance welding, Gas welding, solid state welding, thermo-chemical welding, Intense Energy welding, Weld defects, Other joining processes.

Manufacture of Plastic Components: Types and characteristics of plastics – Molding of polymers– working principles and typical applications

References/Text Material:

1. S. Kalpakjian, "Manufacturing Engineering and Technology," 4th ed. Pearson Education India, 2013.
2. P. N. Rao, "Manufacturing Technology Volume 1," 5th ed. McGrawhill Education, 2018.
3. M. P. Groover, "Introduction to Manufacturing Processes." Wiley, 2011.
4. W. A. J. Chapman, "Workshop Technology, Vol - II." Oxford & IBH Publishing Co. Ltd, 1986.
5. Lindberg Roy, "Processes and Materials of Manufacture." PHI / Pearson Education, 2006.
6. S. Gowri P. Hariharan and A. Suresh Babu, "Manufacturing Technology I." Pearson Education, 2008.
7. P. DeGarmo E., J.T. Black, and R.A. Kosher, "Materials and Processes in Manufacturing," 8th ed. Prentice-Hall of India, 1997.
8. S.K. Hajra Choudhary and A.K. Hajra Choudhary, "Elements of Workshop Technology," Volumes I and II. Media Promoters and Publishers Private Limited, Mumbai, 1997.
9. P.C. Sharma, "A Textbook of Production Technology." S. Chand and Co. Ltd., 2004.
    A. Ghosh and A. B. Mallick, "Manufacturing Science." Prentice Hall PTR, 2001.
10. R. K. Jain, "Production Technology." Khanna Publishers, 2001.

Course Code	Course Name	L	T	P	Credits
ME253	**Machine Dynamics and Vibrations**	**3**	**1**	**0**	**4**

Credit: **4**
Contact hours (L-T-P): **3-1-0**
Overlaps with: **Nil**
Course Assessment Method: **Tutorials, Quizzes, Programming Assignments, and Written Exams**

Course Objective

The aim of this course is to equip students with a profound understanding of dynamic aspects in machinery. Covering flywheels and governors for energy and speed control, balancing of rotating masses, friction devices like belt drives, and essential concepts of gyroscopes and mechanical vibrations, the course prepares students to analyze and design machines with consideration for dynamic forces, balancing, and vibration control.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the vibration principles and effective techniques to control or mitigate vibrations in machines along with various analysis methodologies.
- **CO2.** Gain knowledge of the working principles of flywheels and governors, and understand their practical applications in mechanical systems.
- **CO3.** Explain the principles of gyroscopic action and discover various applications of gyroscopes in areas such as navigation, stabilization, and control systems.
- **CO4.** Acquire skills in balancing rotating masses to reduce dynamic forces, enhance stability, and improve overall machine efficiency.
- **CO5.** Elucidate the principles and applications of friction-based drives, with a focus on belt drive systems

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H		H	H		M			M			L
CO2	H	H	H		M							
CO3	H	H	H									
CO4	H	H	H									
CO5	H	H			H							

Syllabus

Flywheels and Governors: Turning moment diagram, Fluctuation of energy and speed, coefficient of fluctuation of speed, use of crank effort diagram, calculation of flywheel size; Advantages of governors, Analysis of different types of governors, effect of sleeve friction, characteristic of governors, controlling forces curves, sensitivity, hunting phenomena in governors, stability, governor effort and power.

Balancing: Balancing of rotating masses in single plane and in different parallel planes, balancing of slider crank mechanisms, balancing of in-line, V- and locomotive engines.

Friction Devices: Advantages and disadvantages of belt drives system, belt drive system, friction in pivots and collars, power screws, plate and cone clutches, band and block brakes.

Gyroscope: Motion of rigid body in 3- dimensions, Angular momentum, Gyroscopic action, equation for regular precession and gyroscopic torque, applications of gyroscope.

Mechanical Vibrations: Basic terminology related to vibrations; Conservative systems; Free vibrations of systems without and with damping; Equilibrium and energy methods for determining natural frequency of vibratory system; Rayleigh’s method, Free vibrations of system with viscous damping, over damped, critically and under damped systems, logarithmic decrement; Forced vibrations of systems with viscous damping, equivalent viscous damping; Impressed forces due to unbalanced masses and excitation of supports, vibration isolation, transmissibility, whirling of shaft; Introduction to multi degree of freedom system vibrations: Discrete and continuous systems, Numerical methods

References/Text Material:

1. R. L. Norton, "Design of Machinery – An Introduction to the Synthesis and Analysis of Mechanisms and Machines," 6th Ed, McGraw Hill, 2020.
2. S. S. Rattan, "Theory of Machines," 4th Ed, McGraw Hill, 2017.
3. S. S. Rao, "Mechanical Vibrations," 6th Ed, Pearson Education, 2018.
    A. K. Grover, "Mechanical Vibrations," 8th Ed, Nem Chand & Bros, 2009.
4. L. Meirovitch, "Elements of Vibration Analysis," 2nd Ed, McGraw Hill, 1975.
5. N. Sclater and N. P. Chironis, "Mechanisms and Mechanical Devices Sourcebook," 5th Ed, McGraw Hill, 2020.
6. S. Singh, "Theory of Machines," 3rd Ed, Pearson Education, 2012.
7. W. T. Thomson, "Theory of Vibration with Applications," 3rd Ed., CBS Publishers and Distributors, 2003.

Course Code	Course Name	L	T	P	Credits
ME254	Applied Thermodynamics	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0

Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The course aims to discuss the various thermodynamic cycles including power generation refrigeration systems, air-conditioning and analyze them.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Discuss the components in vapor and gas power cycles
- **CO2.** Analyze and evaluate efficiency in steam power plants and IC engines, considering various factors.
- **CO3.** Assess the suitability of different gas turbine engines and combined cycles.
- **CO4.** Solve practical problems on psychrometry, refrigeration, and air-conditioning

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	L		L					M			
CO2	H	H	L	H					M			
CO3	H	M	L	M					M			
CO4	H	H	L	H					M			

Syllabus

Vapour power cycles: Steam Power Plant – Reheat, regenerative steam power cycles, Types of boilers and their attachments. Nozzles; Steam Turbine types and analysis, condensers.

Gas power cycles: IC Engines: SI, CI, two and four-stroke engines, mean effective pressure, efficiency and specific fuel consumption. Conventional and alternative fuels. Pressure-crank angle diagram. Carburettor and fuel injection systems;

Gas Turbine Engines: Types of gas turbine engines. Reheat, intercooling and regenerative cycles. Combined cycles. Introduction to jet propulsion.

Compressors: Reciprocating air compressors: work transfer, volumetric efficiency, isothermal efficiency, multistage compression with intercooling,

Refrigeration and Air-conditioning: Vapour compression and vapour absorption cycles, Air-conditioning Systems. Properties of moist air: psychrometry and psychrometric charts, condensers, and cooling towers.

References/Text Material:

1. Cengel, Y. A. and Boles, M. A., Thermodynamics: An engineering approach, McGraw Hill, 5th ed., 2006
2. Sonntag, R. E., Borgnakke, C. and Van Wylen, G. J., Fundamentals of Thermodynamics, John Wiley, 6th ed., 2003
3. Nag, P. K., Engineering Thermodynamics, Tata McGrawHill, 3rd Ed., 2005
4. Shapiro H.N. and Moran M. J., Fundamentals of Engineering Thermodynamics, Wiley, 8th ed., 2014
5. Eastop and McConkey, Applied Thermodynamics for Engineering Technologists, Pearson, 5th ed., 2020

Course Code	Course Name	L	T	P	Credits
ME255	Thermal Laboratory – I	0	0	3	2

Credit: **2**
Contact hours (L-T-P): **0-0-3**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to make the students exposed to practical applications of fluid mechanics and fluid machinery.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand fundamental fluid mechanics principles, through practical observations like Bernoulli's and Reynolds experiments.
- **CO2.** Develop practical skills in flow measurement techniques.
- **CO3.** Analyze and characterize fluid machinery devices including turbines, pumps, and blowers.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M	M		
CO2	H	H	M	M				M	H	M		
CO3	H	H		M				M	H	M		

List of Experiments

Fluid Mechanics

1. To study and verify the Bernoulli‟s equation
2. Reynold’s experiment,
3. Determination of Metacentric Height
4. To determine the co-efficient of friction (losses) in pipes.
5. To determine minor losses in pipe elements/ arrangements (sudden contraction, sudden enlargement, bend etc.)
6. To determine the flow rate using orifice plate flow meter and measuring nozzle, Venturi nozzle, rotameter
7. To determine the co-efficient of discharge through Venturimeter, Orificemeter, Notch
8. To determine the coefficient of impact of jet on vanes

I.C Engines

1. Function and Working Principle of Ignition System of S.I Engine
2. Function and Working Principle of Injection system (Carburetor and Injector)
3. Function and Working Principle of Lubrication System of IC Engine
4. Detection of Valve Timing Diagram For SI & CI Engines
5. Function and Working Principle of cooling System of IC Engine
6. Measurement of Brake Power, Brake Specific Fuel Consumption by Rope Brake Dynamometer
7. Morse test on IC engine

8. Performance and Emission test on 2 stroke petrol engine (Computerized)
9. Performance and Emission test on 4 stroke MPFI petrol engine, 4 stroke CRDI diesel engine (Computerized)
10. Measurement of viscosity – Redwood viscometer, Saybolt viscometer, Torsion viscometer
11. Measurement of calorific value of fuel using Bomb calorimeter, Junker's gas calorimeter
12. Measurement of flash and fire point – Abel's, Cleveland apparatus

References/Text Material:

1. White, Frank M. Fluid Mechanics. Publisher: McGraw-Hill. Year: 2016.
2. Bansal, R.K. A Textbook of Fluid Mechanics and Hydraulic Machines. Publisher: Laxmi Publications. Year: 2017.
3. Modi, P.N., and Seth, S.M. Hydraulics and Fluid Mechanics Including Hydraulics Machines. Publisher: Standard Publishers Distributors. Year: 2017.
4. Dixon, S.L., and Cesare Hall. Fluid Mechanics and Thermodynamics of Turbomachinery. Publisher: Butterworth-Heinemann. Year: 2014.

Course Code	Course Name	L	T	P	Credits
ME256	**Machine Shop – I**	**0**	**0**	**3**	**2**

Credit: **2**
Contact hours (L-T-P): **0-0-3**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to equip the students with hands-on skills in shaping metal through molding, forging, welding, and lathe operation, mastering tools and techniques for practical projects.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the appropriate tools, materials, instruments required for specific operations in workshop.
- **CO2.** Apply techniques to perform basic operations with molding, forging, plumbing and Pipe fitting
- **CO3.** Understand the figures of the hand tools used for advanced operation in lathe machines

POs → COs ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H				H	M		M		M		H
CO2	H				M	M	L		M	L		L
CO3	H				M	M	L		M	L		H

List of Experiments

1. Study on Sand Mold Preparation using single piece pattern, two piece pattern and three piece patterns.
2. Study on different types of joint by TIG welding and MIG welding.
3. Preparation of models on lathe involving Plain turning, Taper turning, Step turning, Thread cutting, Facing, Knurling, Drilling, Boring.
4. Machining operations on Shaper/Slotter: Flat and bevel surfaces, grooves, slots, guide ways, key ways, etc.
5. Grinding operations using surface grinder

References/Text Material:

1. W. A. J. Chapman, Workshop Technology, Volumes I and II. Oxford & IBH Publishing Co. Ltd., 1986.
2. S. Kalpakjian and S. R. Schmid, Manufacturing Engineering and Technology; 7th ed. Pearson, 2014.
3. Amitabha Ghosh "Manufacturing Science; Publisher: Affiliated East-West Press Pvt. Ltd. Year of Publication: 2010
4. P. N. Rao, Manufacturing Technology- Volume I and II, Metal Cutting and Machining Tools; 4th ed. TMH, 2018.
5. HMT, Production Technology; Tata McGraw Hill Pvt. Ltd., 1998.

Course Code	Course Name	L	T	P	Credits
ME257	Design Laboratory – II	0	0	3	2

Credit: **2**
Contact hours (L-T-P): **0-0-3**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

This lab course aims to determine forces and analyze dynamic systems including vibrations and design aspects through hands-on experimentation and analysis.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Gain knowledge of mass balancing, friction, and journal bearings.
- **CO2.** Acquire competence of vibration analysis of systems
- **CO3.** Design basic machine elements from scratch

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	M	M						M	M		
CO2	H	M	M						M	M		
CO3	H	M	M						M	M		

List of Experiments

1. Determination of natural frequency of single DOF systems (With Matlab, and Simulink)
2. Determine the damping ratio in a damped single degree of freedom system (Simulink Model)
3. Torsional vibration of rotor system
4. Static and dynamic balancing of rotating masses
5. Verification of Gyroscopic rule
6. Study of dynamic friction
7. Pressure distribution in a hydrodynamic bearing
8. Principal stress and strain using strain gauge rosette
9. Stress distribution using photo-elasticity
10. Whirling of shaft
11. Design of shafts
12. Design of couplings

References/Text Material:

1. S. S. Rao, "Mechanical Vibrations." Addison-Wesley, 2010.
2. R. L. Norton, "Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines," 6th ed. McGraw Hill, 2020.
3. S. S. Rattan, "Theory of Machines," 4th ed. McGraw Hill, 2017.
4. V. B. Bhandari, "Design of Machine Elements," 5th ed. McGraw Hill, 2020.
5. V. B. Bhandari, "Machine Design Data Book," 2nd ed. McGraw Hill, 2019.

Sl. No.	Course Code	Course Name	Type	L-T-P	Credits
1	ES300	Environmental Studies	MLC	1-0-0	1
2	ME300	Seminar	DC	0-0-2	1
3	ME5XX	Elective-1	DE/OE*	3-0-0	3
4	ME301	Turbomachines	DC	3-0-0	3
5	ME302	Manufacturing Technology - II	DC	3-0-0	3
6	ME303	Heat Transfer	DC	3-1-0	4
7	ME304	Design of machine elements - II	DC	3-1-0	4
8	ME305	Machine Shop - II	DC	0-0-3	2
9	ME306	Thermal Lab - II	DC	0-0-3	2
Total Credit					**23**

Course Code	Course Name	L	T	P	Credits
ES300	**Environmental Studies**	**1**	**0**	**0**	**1**

Course Objective: Understanding environment, its constituents, importance for living, ecosystem, human developmental activities vs environment, climate change, national and international environment related developments, need for public awareness, its protection and conservation activities.
Course Outcomes: At the completion of this course, the student shall acquire knowledge and ability to,
CO1: Understand in-depth knowledge on natural processes and resources that sustain life.
CO2: Understand the effect of human interference on the web of life, economy, and quality of human life.
CO3: Develop critical thinking for shaping strategies for environmental protection, conservation of biodiversity, environmental equity, and sustainable development.
CO4: Acquire values and attitudes towards understanding complex environmental economic-social challenges, and active participation in solving current environmental problems and preventing the future ones.
CO5: Adopt sustainability as a practice in life, society, and industry.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1		L	L	H		H	H	H	H	L	L	H
CO2		H	H	M	L	H	H	H	H	L	L	H
CO3		H	H	L		H	H	H	M	L	L	H
CO4		L	L	L		L	H	H	L	L	L	H
CO5		H	H	M	M	M	H	H	H	L	M	H

Syllabus

Module 1: Introduction: Environment, interaction organism, scale of interaction, types of environment, Human interference, environmental ethics, environmental problems, sustainable society, ecological foot prints

Module 2: Ecosystem: current status, Role of organism, species, Life supporting system, Factors sustaining life, Components of ecosystem, Ecological efficiency, Matters in ecosystem, Major chemical cycles, Role of Species, Classification of species

Module 3: Biodiversity and species interaction: Biodiversity and Ecosystem, Species interaction, Natural selection, population growth, factor limiting population growth, Population dynamics, Species and reproductive pattern, Biodiversity, Population and Economy, Food and nutrition

Reference Book/Materials

1. Textbook for environmental studies for undergraduate courses of all branches of higher education (Online book-UGC website), Erach Bharucha, University Grants Commission, India.
2. Environmental science: Earth as a living planet, 8th edition, Daniel B. Botkin, Edward A. Keller, John Wiley & Sons, Inc., ISBN 978-0-470-52033-8

3. Environmental science: Problems, concepts, and solutions, 16th edition, G. Tyler Miller, Jr., Scott Spoolman, Brooks/Cole, ISBN-13: 978-0-495-55671-8
4. Principles of environmental science: Inquiry & application, 7th edition, William P. Cunningham, Mary Ann Cunningham, Mcgraw-Hill, ISBN 978–0–07–353251–6
5. Environmental science: A global concern, 12th edition, William P. Cunningham, Mary Ann Cunningham, Mcgraw-Hill, ISBN 978–0–07–338325–5.

Course Code	Course Name	L	T	P	Credits
ME301	Turbomachines	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims at giving an overview of different types of turbo machinery used for energy transformation, such as pumps, fans, compressors, as well as hydraulic and steam turbines.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Gain knowledge of centrifugal pumps, fans, and positive displacement pumps: working principles and performance.
- **CO2.** Understand turbomachine fundamentals: classifications, Euler's equation, velocity triangles, and dimensional analysis.
- **CO3.** Analyze hydraulic turbines: impulse and reaction machines, performance characteristics, and cavitation.
- **CO4.** Perform design calculations of a turbomachine for an appropriate practical application.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	M							M			
CO3	H	H		H					M			
CO4	H	H	H	H					H			

Syllabus

Introduction: Classifications. Euler's equation of Turbomachines. Concept of velocity triangles. Dimensional analysis of incompressible Turbomachines: Similarity laws and model testing, concept of specific speed and specific diameter, unit quantities.

Hydraulic Turbines: Impulse and reaction machines. Analysis of Pelton-Turbine. Analysis of Francis Turbine. Analysis of Kaplan Turbine. Efficiencies, performance characteristics. Cavitation, Thoma’s cavitation factor, Introduction to Wind turbines, Betz limit.

Steam Turbines: Classification, Single-stage impulse turbine, condition for maximum blade efficiency, stage efficiency, Need and methods of compounding, Multi-stage impulse turbine, expression for maximum utilization factor, condition for maximum utilization factor.

Centrifugal Pumps: Pumping systems. Centrifugal pumps working principle. NPSH. Efficiencies, losses, operating characteristics. Priming. Cavitation. Pumps in series and parallel.

Fans, Blowers, and Compressors: Axial fans: velocity triangle, stage parameters, performance characteristics; Centrifugal fan: velocity triangle, stage parameters and performance characteristics; Centrifugal Compressor, Axial Flow Compressors.

Positive Displacement Pumps: Principle, Reciprocating pumps, indicator diagram, slip, effect friction and acceleration, air vessels, two throw and three throw pumps. Constant and variable delivery gear pumps, vane pumps, screw pumps, radial piston pumps.

Power Transmission: Turbomachines used in power transmission: Fluid coupling and torque converter.

References/Text Material:

1. S. L. Dixon, "Fluid Mechanics & Thermodynamics of Turbomachinery," 5th ed. Elsevier, 2005.
2. G. F. Round, "Incompressible Flow Turbomachines," Butterworth and Heinmann, Elsevier, 2004.
3. R. K. Turton, "Principles of Turbomachinery," Chapman and Hall, 1966.
4. B. U. Pai, "Turbomachines," Wiley India, 2013.

Course Code	Course Name	L	T	P	Credits
ME302	**Manufacturing Technology – II**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

This course aims to discuss the metal shaping, equipping the students to master machine tools and manipulate metal through cutting and forming techniques. It aims to understand the forces behind metal removal to wielding lathes and presses with precision.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Develop a comprehensive understanding of machine tools, including their principles of operation and application in various machining processes.
- **CO2.** Understand cutting tools, including their materials, geometries, and characteristics related to wear and performance.
- **CO3.** Explore the mechanics of metal cutting, including the analysis of cutting forces, chip formation, and the dynamic behavior of the cutting tool.
- **CO4.** Gain proficiency in a range of machining processes, such as turning, milling, drilling, grinding, and advanced finishing techniques.
- **CO5.** Understand the fundamentals of metal forming, including press working, forging, extrusion, and rolling operations.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	M	H	M					M			
CO2	H	M		M					M			
CO3	H	H	M	M					M			
CO4	H	M							M			
CO5	H								M			

Syllabus

Metal cutting: Mechanics of metal cutting, merchant's analysis of cutting forces, cutting power, temperature in cutting, Cutting tools and tool materials, geometry, designation, cutting fluids and economics of machining. Tool failure and tool wear

Basic machining processes and machine tools: Lathe, Drilling, Milling-Types, operations, material removal rate, Tool geometry, Shaper, Planer, Slotting, broaching, tapping, boring, planning, shaping, slotting, Grinding processes Gear manufacture, fine finishing operations

Introduction of jigs and fixtures: Basic principles of location, type and mechanics of locating and clamping elements, design of jigs and fixtures.

Modern manufacturing process: Special purpose machine, Modern machining processes: mechanics, process parameters and applications of various non-traditional machining

Automation: Introduction to robotics and automation, Rapid Prototyping processes

References/Text Material:

1. S. Kalpakjian and S. R. Schmid, "Manufacturing Engineering and Technology," 7th ed. Pearson, 2014.
2. P. N. Rao, "Manufacturing Technology-Volume II, Metal Cutting and Machining Tools," 4th ed. TMH, 2018.
3. M. P. Groover, "Principles of Modern Manufacturing," 5th ed. John Wiley, 2014.
4. HMT, "Production Technology." Tata McGraw Hill Pvt. Ltd., 1998.
5. P. C. Pandey and H. S. Shan, "Modern Machining Processes." Tata McGraw-Hill Education Pvt. Ltd., 1980.
6. P. C. Sharma, "A Textbook of Production Engineering." S. Chand & Co., 2006.
7. A. Ghosh and A. K. Mallik, "Manufacturing Science." East-West Press, 2010.
8. P. K. Mishra, "Non-Conventional Machining," 6th ed. Narosa Publishing House, 1997.
9. P. H. Joshi, "Jigs & Fixtures," 3rd ed. McGraw Hill, 2010.
10. M. P. Groover and M. Weiss, "Industrial Robotics: Technology, Programming, and Applications." Mc Graw Hill International Ed.s, 1986.
11. C. K. Chua, K. F. Leong, and C. S. Lim, "Rapid Prototyping: Principles and Applications," 3rd ed. World Scientific Publishers, 2010.

Course Code	Course Name	L	T	P	Credits
ME303	Heat Transfer	3	1	0	4

Credit: **4**
Contact hours (L-T-P): **3-1-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
The main objective of studying this course is to discuss the modes of heat transfer, analyze systems involving heat transfer, and to evaluate the design and analysis of different heat exchangers.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Understand the basic laws of heat transfer.
CO2. Account for the consequence of heat transfer in thermal analyses of engineering systems.
CO3. Obtain numerical solutions for conduction and radiation heat transfer problems.
CO4. Evaluate heat transfer coefficients for natural convection and forced convection.
CO5. Understand and analyze of two phase heat transfer phenomenon.
CO6. Analyze heat exchanger performance by using the method of heat exchanger effectiveness.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	M	M	M					M			
CO3	H	H	M	M					M			
CO4	H	H	M	H					M			
CO5	H								M			
CO6	H	H	M	H					M			

Syllabus

Introduction to Heat Transfer and Concepts: Thermodynamics versus Heat Transfer, Modes of heat Transfer, Basic laws of Heat Transfer.

Conduction: General heat conduction equation in cartesian, cylindrical & spherical coordinates, Initial and Boundary conditions, One dimensional steady state conduction, Thermal contact resistance, Critical radius of insulation, Conduction with Heat Generation, Heat Transfer from Extended Surfaces: Generalized Fin Equation, Heat dissipation from fins, Fin effectiveness & efficiency.

Natural Convection: Physical Mechanism of Natural Convection – Grashoff's number, Natural Convection over surfaces – natural convection correlations, Natural Convection inside enclosures – effective thermal conductivity, Natural convection from finned surfaces.

Forced Convection: Physical Mechanism of forced Convection, Velocity boundary layer – laminar & turbulent flows, Reynolds number, Thermal Boundary layer, Flow over flat plates – laminar & turbulent flows, Combined Laminar & turbulent flow , Flow across Cylinders & spheres –the Drag coefficient, the heat transfer coefficient , Flow in tubes.

Radiation Heat Transfer: Thermal Radiation, Blackbody radiation , Radiation properties, Various laws, Gray body & selective emitters, Intensity of Radiation & Lambert's Cosine Law, Atmospheric and solar radiation. Radiation Exchange between Surfaces: View factor, Radiation heat transfer – black surfaces, diffuse and gray surfaces, Surface and space resistance, Electrical approach for radiation heat exchange, Radiation shields.

Boiling and Condensation: Boiling heat transfer, pool boiling regime, condensation heat transfer, film condensation – vertical plate, sphere, horizontal cylinders, Drop wise condensation.

Heat Exchangers: Classification, Overall heat transfer coefficient, The LMTD Method for Heat exchanger analysis, Correction for LMTD for use with cross flow &multi pass exchangers, e – NTU method for heat exchanger analysis.

References/Text Material:

1. Y. A. Cengel, "Heat Transfer: A Practical Approach," 2nd ed. McGraw Hill, 2002.
2. T. L. Bergman, A. S. Lavine, F. P. Incropera, and D. P. DeWitt, "Fundamentals of Heat and Mass Transfer," 7th ed. John Wiley & Sons, 2012.
3. N. M. Ozisik, "Heat Transfer - A Basic Approach," McGraw Hill, 1985.
4. J. P. Holman and S. Bhattacharyya, "Heat Transfer," 10th ed. McGraw Hill, 2017.
5. S. P. Sukhatme, "A Textbook on Heat Transfer," 4th ed. Universities Press, 2012.

Course Code	Course Name	L	T	P	Credits
ME304	**Design of Machine Elements - II**	**3**	**1**	**0**	**4**

Credit: **4**
Contact hours (L-T-P): **3-1-0**
Overlaps with: **Nil**
Course Assessment Method: **Tutorials, Quizzes, Projects, and Written Exams**

Course Objective

The aim of the course is to empower students with a thorough understanding of machine design principles applied to design of machine elements such as fasteners, riveted, bolted and weld joints, gears, springs, and friction clutches etc. This course also provides for a basic understanding of tribological aspects like lubrication, and bearings in machine design.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Understand the design process of detachable and permanent joint elements, and various joint designs with their force analysis.
CO2. Comprehend the dynamics of gears and gear-trains and design them for different input conditions and constraints.
CO3. Comprehend the principles of lubrication and bearings, and design contact bearings for varied applications.
CO4. Design and analyze miscellaneous machine elements, including clutches, brakes, couplings and pressure vessels.
CO5. Understand the statistical aspects in any design process, and its importance and relevance in practical machine design.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H						M					
CO2	H	H	H	H								H
CO3	M	H	H	H								H
CO4	M	H	H	H		M	M	H	H	M	M	H
CO5	H	H	H	H								H

Syllabus

Design of Machine Elements:

1. Design of threaded fasteners and coil springs.
2. Design of riveted and welded joints.
3. Design of spur, and helical gears and gear trains.
4. Design of rolling and sliding contact bearings.
5. Design of clutches, brakes & couplings.
6. Design of cylinders and pressure vessels.

Statistical Consideration in Design: Frequency curves, dispersion, probability distribution, propagation of error and reliability.

References/Text Material:

1. R. L. Norton, "Machine Design – An Integrated Approach," 6th ed. Pearson Education, 2019.
2. R. G. Budynas and J. K. Nisbett, "Shigley's Mechanical Engineering Design," 10th ed. McGraw Hill, 2014.
3. V. B. Bhandari, "Design of Machine Elements," 5th ed. McGraw Hill, 2020.
4. K. Achhangham, "Design Data: Data Book of Engineers," PSG Tech, 2020.
5. R. C. Juvinall and K. M. Marshek, "Fundamentals of Machine Component Design," 7th ed. Wiley, 2020.
6. K. Mahadevan and K. B. Reddy, "Design Data Handbook for Mechanical Engineering," 4th ed. CBS Publishers, 2019.
7. V. B. Bhandari, "Machine Design Data Book," 2nd ed. McGraw Hill, 2019.

Course Code	Course Name	L	T	P	Credits
ME305	**Machine Shop – II**	**0**	**0**	**3**	**2**

Credit: 2
Contact hours (L-T-P): 0-0-3
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The course aims to expose students the traditional machining including milling, drilling, shaping, gear cutting, and grinding to cutting-edge 3D printing to shape intricate parts with precision and purpose.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Perform diverse machining operations—milling, drilling, shaping, gear cutting, and grinding—to shape and refine components.
- **CO2.** Gain hands-on experience in advanced technologies—CNC machining, 3D printing, robotic welding—enhancing innovation and efficiency.
- **CO3.** Acquire skills in measuring and analyzing forces, surface finish, temperature, and tool life for machining optimization.
- **CO4.** Apply processes like laser sintering and fused deposition modeling for intricate 3D part creation in rapid prototyping.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	M	M	M	M				M	M		
CO2	H	M	H	H	H				M	M		
CO3	H	M	M	M	M				M	M		
CO4	H	M	M	H	H				M	M		

List of Experiments

1. Advanced Manufacturing process.- EDM, CNC Machining, 3D printing
2. CNC part programming and operation – Simple Turing, Milling
3. Different types of Gear cutting in milling machine.
4. Modern trends in manufacturing, automation, NC/CNC, FMS, CAM and CIM.
5. Study on advanced welding process.- Laser, Plasma/Robotic welding
6. A group project on fabrication and assembly of a part/product.

References/Text Material:

1. W. A. J. Chapman, "Workshop Technology," Volumes I and II. Oxford & IBH Publishing Co. Ltd., 1986.
2. S. Kalpakjian and S. R. Schmid, "Manufacturing Engineering and Technology," 7th ed. Pearson, 2014.
3. P. N. Rao, "Manufacturing Technology- Volume I and II, Metal Cutting and Machining Tools," 4th ed. TMH, 2018.
4. HMT, "Production Technology." Tata McGraw Hill Pvt. Ltd., 1998.
5. M. P. Groover, "Principles of Modern Manufacturing," 5th ed. John Wiley, 2014.

6. ASTME, "Fundamentals of Tool Design," 6th revised ed. Prentice Hall of India, 2010.
7. C. K. Chua, K. F. Leong, and C. S. Lim, "Rapid Prototyping: Principles and Applications," 3rd ed. World Scientific Publishers, 2010.
8. Gibson, D. W. Rosen, and B. Stucker, "Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing." Springer, 2010.

Course Code	Course Name	L	T	P	Credits
ME306	Thermal Laboratory – II	0	0	3	2

Credit: **2**
Contact hours (L-T-P): **0-0-3**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to expose students to the practical aspects of heat transfer, heat exchangers, and boilers. It also aims to determine forces and analyze dynamic systems including vibration and balancing of masses through hands-on experimentation and analysis.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

CO4. Develop practical understanding of heat transfer phenomena, including thermal conductivity, heat transfer coefficients, heat exchanger analysis, and boiling and condensation experiments.
CO5. Gain knowledge of mass balancing, friction, and journal bearings.
CO6. Acquire competence of vibration analysis of systems

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H		M						M	M		
CO2	H	M	M						M	M		
CO3	H	M	M						M	M		

List of Experiments

<u>Heat Transfer</u>

1. Thermal conductivity of plane wall/metal rod, Gases, liquids
2. Heat transfer through composite wall, lagged pipe, Fin, heat pipe
3. Analysis of parallel and counter flow heat exchangers (Fin Tube, Shell & Tube)
4. Determination of heat transfer coefficient in natural and forced convective flows
5. Boiling experiment by determining different boiling regimes and critical heat flux
6. Condensation experiment – dropwise, and film wise
7. Determination of Stefan Boltzmann constant
8. Study of un-steady state of heat transfer (To determine heat transfer coefficient over a cylindrical body under transient conditions)

<u>Refrigeration and Air Conditioning</u>

1. Determination of dryness fraction of steam
2. Performance test on single stage and multi-stage air compressor test rig
3. Performance test on Vapour compression refrigeration system
4. Performance test on Vapour absorption refrigeration system
5. Performance test on heat pump test rigs
6. Psychrometric testing on air conditioning test rig
7. Study of COP of Cooling Coil in Sensible Cooling Process

Fluid Machines

1. Performance Characteristics of Pelton Wheel,
2. Performance Characteristics of Francis Turbine,
3. Performance Characteristics of Kaplan Turbine,
4. Performance Characteristics of Centrifugal pump,
5. Performance Characteristics of Reciprocating pump,
6. Performance Characteristics of Gear pump,
7. Performance Characteristics of Reciprocating Compressor
8. Performance Characteristics of Centrifugal blower

References/Text Material:

1. F. P. Incropera, D. P. DeWitt, T. L. Bergman, and A. S. Lavine, "Fundamentals of Heat and Mass Transfer," 7th ed. Wiley, 2011.
2. Y. A. Cengel, "Heat and Mass Transfer: Fundamentals and Applications," 5th ed. McGraw-Hill Education, 2014.
3. S. S. Rao, "Mechanical Vibrations." Addison-Wesley, 2010.

VI SEMESTER

Sl. No.	Course Code	Course Name	Type	L-T-P	Credits
1	HU350	Professional Ethics and Human Values	MLC	1-0-0	1
2	IK350	Indian Knowledge System	IKS (OE)		3
3	ME350	Metrology	DC	3-0-0	3
4	ME351	Computer Aided Engineering	DC	3-1-0	4
5	ME352	Industrial Engineering	DC	3-0-0	3
6	ME5XX	Elective-2 (Non-Minor students)	DE	3-0-0	3
7	ME353	Computer Aided Engineering (CAE) Lab	DC	0-0-3	2
8	ME354	Metrology Lab	DC	0-0-3	2
Total Credit					**21**

*A student can register only one open elective (OE) per semester and a maximum of two OE in the B.Tech. tenure. This is excluding the Indian Knowledge system (IKS) course offered in 7th semester. Since, IKS is mandatory OE, students are not allowed to register for an OE in that semester.

Course Code	Course Name	L	T	P	Credits
HU350	**Human Values & Professional Ethics**	**1**	**0**	**0**	**0**

Course Objectives:
The main objective is to inculcate human values and professional ethics among the students so that they become good human beings, which in turn will bring collective benefits. Also, the students will understand harmony at all levels of existence.

Course Outcomes
After this course, the student shall acquire knowledge of Human Values and ethics and there will be a behaviour change. They will understand the value of harmonious relationships with fellow human beings based on trust, respect, compassion, tolerance, and empathy.
.

CO1. Students will have a fair understanding of Human Values and Professional Ethics
CO2. Students will exemplify good behaviour
CO3. Students will develop a feeling of Empathy

Relationship of Course Outcomes to Program Outcomes
H = High correlation; M = Medium correlation; L = Low correlation

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1						M		H				L
CO2						M		H				L
CO3						H	M					L

Syllabus

Module 1: Introduction to Concepts of Human Values and Ethics- Origin and History (Western and Eastern Perspectives with reference to Socrates, Plato, Plotinus, Epicurus,Thomas Aquinas, Immanuel Kant, Buddha, *The Vedas*, *The Upanishads* and *The Mahabharata*) Ethics – Classification (4 Types), History, and Purposes, Utilitarianism, Duties, Rights, Responsibility, Virtue, Honesty, Morality, Moral Autonomy, Obligations of Engineering Profession and Moral Propriety.

Module 2: A comprehensive understanding of Existence, Knowledge of Self, Knowledge of Society, Nature vis-à-vis Culture, Anthropocentrism, Deep Ecology, Idea of Cosmos

Module 3: Ability to identify the scope and characteristics of people-friendly and eco-friendly production systems, technologies, and management models, Engineer's Moral responsibility for Safety and Human Rights, Risk Assessment and Communication, Product Liability, Engineers-Employers Liaison, Whistle-Blowing and its Justification, Cyber Crime and Cyber Ethics, and Ecoethics

Module 4: Case study Discussion of typical holistic technologies, management models and production systems, Strategy for the transition from the present state to Universal Human Order

Module 5: Rapid Reading of texts like *Justice*, *Crime and Punishment*, *The Model Millionaire*, & Films Discussion like *An Inconvenient Truth*, *Modern Times*, and *The Elephant Whisperers* to understand Universal Human Values.

Reference Books/Material

1. A. N. Tripathy, 2003, *Human Values*, New Age International Publishers.
2. B P Banerjee, 2005, *Foundations of Ethics and Management*, Excel Books
3. B L Bajpai, 2004, *Indian Ethos and Modern Management*, New Royal Book Co., Lucknow. Reprinted 2008.
4. E.F. Schumacher, 1973, *Small is Beautiful: a study of economics as if people mattered*, Blond & Briggs, Britain
5. Ralph T.H. Griffith, (Trans) *The Vedas*
6. Eknath Easwaran, (Trans) *The Upanishads*
7. Peter Brook directed *The Mahabharata* (1989) film [available on Youtube]

Course Code	Course Name	L	T	P	Credits
ME350	Metrology	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The objective of this course to gain knowledge on the evolution of quality standards and metrology and provide knowledge of limits, fits, tolerances and gauging. It is objective is to provide description and principle of various Measurement systems and methods for surface finish, threads and gear.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to –

CO1. Understand importance of measurements and standards
CO2. Know various measurements devices used for measurement and maintain standard
CO3. Understand Quality control fundamentals
CO4. Understand the concept of Limit fits and tolerances
CO5. Know various Surface finish measurement techniques, optical, screw thread and gear measurement
CO6. Know how to conduct acceptance test of various machines

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H				H	M		H				H
CO2	H		M		H	M		M	M			M
CO3	H	H	H	L	H	M		L		M		
CO4	H	H	H	L	H	M		L		M		
CO5	H		M		H	M		M	M			M
CO6	H		M		H	M		M	M			M

Syllabus

Introduction to Metrology: Standards, Errors in measurement, calibration, Linear, angular measurement

Comparators: Constructional features and operation of mechanical, optical, electrical/electronic and pneumatic comparators, advantages, limitations and field of applications, Limits and Tolerances, statistical aspect of tolerances and setting tolerances,

Surface Texture Measurement: Surface finish terminology and measurement, Optical measuring instruments

Measurement of screw thread and Gear elements: Screw Thread Measurement using Two wire and three wire methods, floating carriage micrometer. Gear Measurement using Gear tooth comparator, Master gears, measurement using rollers and Parkinson's Tester.
Quality control fundamentals: Standard deviation, normal curve pattern of variations, control charts for variables, Quality control tools
Special measuring equipment and Acceptance test for machines: Principles of interference, concept of flatness, flatness testing, optical flats, optical interferometer and laser interferometer, Acceptance test on lathe machine and Milling machine

References/Text Material:

8. C. Gupta, "Engineering Metrology," Dhanpat Rai Publications, New Delhi, 1994.
9. Grant, "Statistical Quality Control," Mc Graw Hill Publication, 6th ed., 1988.
10. R. K. Rajput, "Mechanical Measurements and Instrumentation (Including Metrology and Control Systems)", S. K. Kataria and Sons, 2013.

Course Code	Course Name	L	T	P	Credits
ME351	Computer Aided Engineering	3	1	0	4

Credit: **4**
Contact hours (L-T-P): **3-1-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

This comprehensive course will equip the students with the foundational knowledge and practical skills of computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering (CAE). It delves into geometric modeling techniques, explore the power of finite element analysis for virtual simulation, and also discuss CNC programming.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Apply principles of computer graphics
CO2. Understand finite element analysis
CO3. Gain knowledge in computer numerical control programming
CO4. Concepts of digital manufacturing technologies

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H		M					M			
CO2	H			M					M			
CO3	H	M	M	M	M				M			
CO4	H	L	M	M	M				M			

Syllabus

Fundamentals: Definitions of CAD, CAM, and CAE, hardware and software components, basic concepts of graphics programming.

Geometric Transformations: 2D and 3D transformations, homogeneous representation of transformation, concatenation of
transformations, hidden-line and hidden-surface removal, rendering.

Geometric Modelling: Wireframe modelling, surface modelling, solid modelling, mathematical models for representing geometry, curves representation, parametric and non-parametric form, properties of curve representation, interpolation and approximation, blending functions, 3D space curves, spline, cubic spline, B-spline, Bezier curves, properties of Bezier curves, Hermite curves, comparison of curves, 3D surfaces, Super-quadric surfaces.

Introduction to finite element analysis: general steps involved, element types, general structure of commercial finite element program packages, types of analysis.

Introduction to computer numerical control: CNC hardware basics, CNC programming.

Advanced Topics in CAE: Computer aided process planning, flexible manufacturing systems, additive manufacturing technologies, Concept of Design Optimization

References/Text Material:

1. K. Lee, "Principles of CAD/CAM/CAE systems," Addison-Wesley Longman Publishing Co., Inc., 1999.
2. P. N. Rao, "CAD/CAM: principles and applications," Tata McGraw Hill Education Private Limited, 2004.
3. P. Radhakrishnan, S. Subramanyan, and V. Raju, "CAD/CAM/CIM," New Age International, 2008.
4. A. Angel, "Interactive Computer Graphics: A top-down approach with OpenGL," Addison-Wesley Longman Publishing Co., Inc., 1996.
5. S. S. Rao, "The finite element method in engineering," Butterworth-Heinemann, 2017.

Course Code	Course Name	L	T	P	Credits
ME352	Industrial Engineering	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
This course aims to provide knowledge and training in Work study and Ergonomics to be applied in industry. Also, the course aims to make one understand the different optimization techniques for engineering problems.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Use the work study techniques to improve the productivity
CO2. Know the ergonomics practices to be implement in industrial application
CO3. use the optimization techniques for engineering and Business problems

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H	H	M	M	L	M	H	H	M	M	M
CO2	H	H	H	M	M	M		H	H	M		M
CO3	H	H	M	M	H	M						

Syllabus

Productivity: Productivity and living standards – work design and Productivity – Productivity measurement-Productivity models, scope of motion and time study - Work methods design.

Method Study: Total work content, developing methods – operation analysis, tools for method analysis , flow process macro analysis, operation – micro analysis, therbligs,multiple activity chart, motion & micro motion study, graphic tools. Method study in office

Work Measurement: Stop watch time study, Performance rating, allowances, standard data-machining times for basic operations, learning effect

Applied Work Measurement: Methods time measurement (MTM), Work sampling – Determining time standards from standard data and formulas-Predetermined motion time standards – work factor system – methods time measurement, Analytical Estimation, Measuring work by physiological methods – heart rate measurement – measuring oxygen consumption– establishing time standards by physiology methods.

Ergonomics: Motion economy- Ergonomics practices – human body measurement – layout of equipment – seat design - design of controls and compatibility – environmental control – vision and design of displays, design of work space, chair table.

Introduction to operations research: Linear programming, Graphical method, Simplex method, Dual problem, dual simplex method, Concept of unit worth of resource, sensitivity analysis; Transportation problems, Assignment problems; Integer and Dynamic programming; Network flow models, CPM and PERT; Queuing models.

References/Text Material:

1. B. W. Niebel, "Motion and Time Study," 9th ed. Richard D. Irwin Inc, 2009.
2. R. M. Barnes, "Motion and Time Study," John Wiley, 2002.
3. "Introduction to Work Study," 3rd ed. ILO, Oxford & IBH Publishing, 2001.
4. R. S. Bridger, "Introduction to Ergonomics," McGraw Hill, 2008.
5. P. Vrat, "Productivity Management - A Systems Approach," Narosa Publishing, 1998.
6. S. L. Narasimhan, D. W. McLeavey, and P. J. Billington, "Production, Planning and Inventory Control," Prentice Hall, 1997.
7. J. L. Riggs, "Production Systems: Planning, Analysis and Control," 3rd ed. Wiley, 1981.
8. J. K. Sharma, "Operations Research," Macmillan, 1997.
9. J. Muhlemann, J. Oakland, and K. Lockyer, "Productions and Operations Management," Macmillan, 1992.
10. H. A. Taha, "Operations Research - An Introduction," Prentice Hall of India, 1997.

Course Code	Course Name	L	T	P	Credits
ME353	Computer Aided Engineering (CAE) Laboratory	0	0	3	2

Credit: **2**
Contact hours (L-T-P): **0-0-3**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to equip students with the simulation environment by developing skills of different pre-processing, solving, and post-processing techniques for a given mechanical system. The course also aims to expose them to CNC part programming and interfacing with CAD and CAM.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Develop proficiency in solid modeling software and its key operations for creating and editing 3D models.
- **CO2.** Acquire practical knowledge of Finite Element Method (FEM) for structural, thermal, and fluid flow analysis.
- **CO3.** Gain skills in CNC part programming for lathe and machining centers to effectively utilize CNC machines.
- **CO4.** Understand the interface between CAD and CAM systems for seamless data exchange and integration. Explore rapid prototyping principles and practices for efficient realization of 3D designs.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H	H		H				M	M		
CO2	H	M	H	H	H			M	M	M		
CO3	H	H	M	H	H			M	M	M		
CO4	H	M	M		H			M	M	M		

Syllabus

Introduction to solid modelling software: Curves and surfaces generation, solid creation operations: primitive solids, extrude, loft, sweep, revolve, etc., familiarity with solid editing operations: union, subtract, intersect, fillet, chamfer, offset, taper, slice, thicken, etc., windowing, clipping, scaling and rotation transformations, solid modeling practices.

Familiarization and problem solving in FEM software: Mesh generation, static and dynamic analysis, post processing.

CNC Part Programming: Fundamentals, exercises on CNC lathe and machining center/milling machines, rapid prototyping.

CAD/CAM Interface: Interfacing CAD and CAM and generated programs by CAM software further used for actual machining.

Robot programming for various operations and PLC programming and testing.

References/Text Material:

1. D. Planchard, "SOLIDWORKS 2021 Reference Guide," SDC Publications, 2021.
2. ANSYS, "ANSYS User Manual."
3. P. N. Rao, "CAD/CAM: Principles and Applications," Tata McGraw Hill Education Private Limited, 2004.

Course Code	Course Name	L	T	P	Credits
ME354	**Metrology Laboratory**	**0**	**0**	**3**	**2**

Credit: **2**
Contact hours (L-T-P): **0-0-3**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to apply scientific and engineering principles to design, build, and utilize mechanical measurement in various systems.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Apply scientific principles for effective solutions in mechanical measurement, addressing challenges practically with engineering knowledge.
- **CO2.** Design, execute, and analyze experiments, enabling informed decision-making in mechanical measurement through meaningful insights.
- **CO3.** Attain proficiency in designing tailored measurement systems for optimal functionality, meeting specific task requirements with accuracy.
- **CO4.** Perform interdisciplinary tasks in Mechanical Measurement, promoting collaboration, communication, and integrated problem-solving across diverse expertise.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H		H					M			
CO2	H	M		H					M			
CO3	H		H	H	M			M	M	M		
CO4	H	M		H				M	M	M		

List of Experiments

1. Introduction to Metrology and linear measurement-slip gauge, depth micrometer bore gauge, telescopic gauge.
2. Angular Measurement: Sine bar/Sine center, Bevel Protractor, slip gauges.
3. Linear and angular measurement using Profile Projector.
4. Use of Dial Gauge as Mechanical Comparator.
5. Measurement of straightness, roundness and squareness.
6. Study the straightness error using autocollimator and spirit level
7. Measurement of Surface Roughness using Surface Roughness Tester.
8. Measurement of various elements of screw thread using Tool Makers Microscope, Three wire method.
9. Measurement of Gear tooth thickness
10. Linear and angular measurement using Profile Projector.
11. Measurement of features in a prismatic component using Coordinate Measuring Machine (CMM)
12. Studies on the surface non-contact 3D profilometer

13. Use of various metrological tools like feeler, taper, fillet, and various types of gauges.

References/Text Material:

1. S. Kalpakjian and S. R. Schmid, "Manufacturing Engineering and Technology," 7th ed. Pearson, 2014.
2. I. C. Gupta, "Engineering Metrology," Dhanpat Rai and Sons, 2003.

VII SEMESTER

Sl. No.	Course Code	Course Name	Type	L-T-P	Credits
1	ME400	Summer Project/ Industrial Training	DC	0-0-2	1
2	ME401	Comprehensive Examination	DC	0-0-0	1
3	ME402	Major Project-I	DC	0-0-3	2
4	HS350	Industrial Economics	HU&HS	3-0-0	3
5	ME5XX	Elective-3	DE/OE*	3-0-0	3
6	ME5XX	Elective-4	DE/OE*	3-0-0	3
7	ME5XX	Elective-5	DE/OE*	3-0-0	3
8	ME5XX	Elective-6	DE/OE*	3-0-0	3
Total Credit					**19**

Course Code	Course Name	L	T	P	Credits
HS353	**Industrial Economics**	**3**	**0**	**0**	**3**

COURSE OBJECTIVES

1. Identify and analyse the behaviour of a firm under different market situations systematically.
2. Understand and assimilate the issues related to strategic behaviour in firms, R&D and innovation.
3. Have a comprehensive coverage of firms' profitability and efficiency measurements, with applications to India's industrial structure.
4. To understand the rich complexities and paradox of fourth industrial revolution.

COURSE OUTCOMES

Upon completion, students should have an in-depth knowledge of

CO1. Market structure, conduct and performance
CO2. Strategic behaviour in firms
CO3. Innovation, R&D and the market
CO4. Industrial efficiency and its applications for the Indian economy.

Relationship of Course Outcomes to Program Outcomes H = High correlation; M = Medium correlation; L = Low correlation

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H	M	M	M	M	M	M	M	M	L	M
CO2	M	H	H	M	M	H	M	M	H	M	M	M
CO3	M	M	H	H	H	M	M	M	H	M	M	M
CO4	H	M	M	M	L	L	H	H	M	M	M	H

SYLLABUS

Unit-1: Introduction to Economics – Introduction to Industrial economics - nature and scope - concept of firm and industry- types of firms - structure, conduct and performance. **[5 hours]**

Unit-2: Standard forms of market structure - pricing strategies and output determination of firms - profit maximization, sales maximization (William J. Baumol), utility maximization (Oliver E. Williamson), growth maximization (George K. Yarrow) - equilibrium of firms under perfect competition, monopoly, monopolistic competition and oligopoly - optimum price and output - economies of scale. **[10 hours]**

Unit-3: Price and non-price competition - strategic behaviour of firms - collusion and mergers - game theory - market failures and information asymmetry - advertising and product differentiation - market entry and exit - concentration and diversification. **[10 hours]**

Unit- 4: Patents and technological change- the economics of patent-innovation and diffusion measures of concentration **[5 hours]**

Unit- 5: Research and Development (R&D) and market structure -- product and process innovation- R&D and patent race-licensing and incentive to innovate **[6 hours]**

Unit-6: Economics of the fourth Industrial Revolution – Industrial revolution past, present and Future, Internet-Artificial Intelligence- Blockchain technologies **[6 hours]**

ESSENTIAL READING

1. Donald A. Hay, Derek J. Morris, *Industrial Economics: Theory and Evidence*, Oxford University Press, 1979
2. Carton, D. and J. Perloff. Modern Industrial Organization (Reading, Massachusetts: Addison-Wesley), 1999.
3. Lall, Sanjaya. Competitiveness, Technology and Skills (Cheltenham: Edward Elgar), 2001.
4. Shy, O. (1996). *Industrial organization: Theory and applications*. MIT Press.

SUPPLEMENTARY READING

1. A. Singh and A.N. Sandhu, *Industrial Economics*, Himalaya Publishing House, Bombay, 1988
2. Ferguson, Paul R. and Glenys J. Ferguson, (1994), Industrial Economics - Issues and Perspectives, Macmillan, London.
3. Stephen Martin, *Advanced Industrial Economics*, Oxford, UK Blackwell Publisher, 2002
4. R. R. Barthwal, *Industrial Economics: An Introductory Textbook*, New Age International Publishers, 2007
5. Hay, Donald A. and Derek J. Morris. Industrial Economics and Organization: Theory and Evidence, 2nd Edition (Oxford: Oxford University Press), 1991.
6. Schmalensee, R., Inter-industry studies of Structure and Performance, in Schmalensee, R. and R. D. Willig (eds.): Handbook of Industrial Organization [Amsterdam: North-Holland] Vols. 2 Chapter 16, pp. 951-1009, 1989.
7. Siddharthan, N. S. and Y.S. Rajan. Global Business, Technology and Knowledge Sharing: Lessons for Developing Country Enterprises (New Delhi: Macmillan), 2002.
8. Tirole, Jean. The Theory of Industrial Organization (Cambridge, MA: The MIT Press), 1988.

VIII SEMESTER

Sl. No.	Course Code	Course Name	Type	L-T-P	Credits
1	ME450	Major Project-II	DC	0-0-6	3
2	ME5XX	Elective-7	DE/OE*	3-0-0	3
3	ME5XX	Elective-8	DE/OE*	3-0-0	3
4	ME5XX	Elective-9	DE/OE*	3-0-0	3
5	ME5XX	Elective-2 (Minor students)##	DE/OE*	3-0-0	3
	Total Credit				**12**

Total credit for Minor students in VIII semester is 15.

DEPARTMENT ELECTIVES

Course Code	Course Name	L	T	P	Credits
ME500	Automatic Control	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
This course aims to impart knowledge to analyze, design, and control dynamic systems from simple mechanical models to complex industrial processes. The classical and modern control theories are discussed, learning to craft precise feedback mechanisms and tune parameters for optimal stability and performance.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Develop a comprehensive understanding of automation technologies, including its definitions, principles, and applications.
- **CO2.** Understand how control systems are represented and modeled using diagrams and equations.
- **CO3.** Analyze and design control systems by studying their response to changes and ensuring stability.
- **CO4.** Explore the behavior of control systems at different frequencies and learn how to assess their stability.
- **CO5.** Design various types of controllers and learn methods for tuning them to achieve desired performance.
- **CO6.** Gain practical knowledge of digital control systems and simulate their behavior using MATLAB.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H		L						M			
CO2	H		L						M			
CO3	H	H	M	M					M			
CO4	H	H	H	M					M			
CO5	H	H	H	M					M			
CO6	H	M	M	M	H				M			

Syllabus

Introduction to control system engineering: history, representation of feedback control system by block diagrams, signal flow graphs, physical systems and their mathematical models; representation of linear time invariant systems; order of the system; classical method; transfer function approach; block diagram reduction; state space representation; mathematical models of mechanical, electrical, hydraulic and pneumatic elements and systems;

Transient response analysis: solution of first order, second order and higher order systems, solution by Laplace transform, solution of states space equation, performance parameters of first order and second order systems; stability of systems, Routh-Hurwitz criterion, steady state error, error constants, improving time response and steady state error, root locus techniques: analysis and design.

Frequency response of systems: plotting the frequency response, rectangular plots, polar plots, Bode plots and Nichols chart; stability analysis: Bode plot, Nyquist plots and Nyquist criterion, gain margin, phase margin. Design of control systems: design philosophy, design of lead, lag, lead-lag, proportional, integral, derivative, PID controllers, tuning of controllers and PID controller gain tuning techniques;

Modern Control Concepts: State space model of control system, conversion of state space to transfer function and transfer function to state space, design of controllers via state space, controllability and observability.

Introduction to digital control systems: Sample data systems, Z transform of discrete signals. Performance of a sample data second order system. Root locus of digital control systems. Stability analysis in the Z plane.

Introduction to control system on MATLAB platform: Introduction to control system on MATLAB platform. MATLAB commands and control system toolbox. Analysis of transient response of control system through MATLAB commands. Root locus and BODE plot on MATLAB figure window. Simulation of digital control system using MATLAB.

References/Text Material:

1. K. Ogata, "Modern Control Engineering," 5th Ed., Pearson, 2009.
2. B.C. Kuo, "Automatic Control Systems," 9th Ed., Wiley, 2014.
3. G.F. Franklin, J.D. Powell, and A.E. Naeini, "Feedback Control of Dynamic Systems," 4th Ed., Prentice Hall, 2002.
4. Nise, "Control System Engineering," Wiley, 1995.
5. M. Gopal, "Control Systems: Principles and Design," 2nd Ed., TMH, 2002.
6. I.J. Nagrath and M. Gopal, "Control Systems Engineering," 6th Ed., New Age International, 2017.

Course Code	Course Name	L	T	P	Credits
ME501	Advanced Mechanics of Solids	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The course aims to provide an in-depth exploration of advanced concepts in mechanics of solids, focusing on nonlinear material behavior, structural stability, and advanced analytical and numerical methods for solving complex problems in solid mechanics.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Comprehend typical forms of constitutive behavior (elasticity, plasticity, creep, Newtonian and non-Newtonian fluids, etc.) and the ability to design new constitutive laws.
- **CO2.** Understand the principle of material frame indifference, and the second law of thermodynamics and their role in continuum physics.
- **CO3.** Understand finite deformation of a member subjected to combined loads

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H			M					M			
CO3	H	H	M						M			

Syllabus

Introduction: Summation convention, vectors and their operations, vector space, linear transformations, tensors, dual basis, operation with tensors, Transformation of tensor components, Calculus of Vectors and Tensors.

Kinematics of deformation: Lagrangian and Eulerian frameworks, Deformation gradient, Longitudinal strain, shear strain, relating deformed and undeformed surface and volume elements.

Introduction to stress analysis in elastic solids: Stress at a point, Stress tensor, Stress components in rectangular coordinate systems, Cauchy and 1st P-K Stress tensor, Stress transformation, Principal stresses and planes, Hydrostatic and deviatoric stress components, Compatibility conditions.

Balance equations: Mass conservation, Linear and angular momentum balance in Lagrangian framework,

Constitutive relation: St. Venant Kirchhoff isotropic model, linearized isotropic stiffness tensor, Ogden material model, on boundary condition, Uniqueness theorem, Castigliano's Theorem.

2D Problems in Elasticity: Plane stress and plane strain problems, Stress compatibility equation, Airy's stress function and equation, Polynomial method of solution, Solution for bending of a cantilever beam with an end load.

Unsymmetrical bending: Straight beams Curved beams, Shear center of thin-walled open sections with one axis of symmetry.

Torsion of non-circular bars: Solutions for circular and elliptical cross-sections using St. Venant's theory and Prandtl's method, Torsion of thin-walled tubes, Shear flow.

Energy Methods: Principle of virtual work, Principle of minimum potential energy.

Application to non-linear elasticity: Finite extension-torsion-inflation in cylindrical tubes.

References/Text Material:

2. S. Timoshenko and J. N. Goodier, "Theory of Elasticity," 3rd ed. McGraw-Hill International, 1970.
3. L. S. Srinath, "Advanced Mechanics of Solids," Tata McGraw Hill Company.
4. C. L. Dym and I. H. Shames, "Solid Mechanics: A Variational Approach," McGraw Hill, 1973.
5. S. Singh, "Theory of Elasticity," Khanna Publisher.
6. R. Abeyaratne, "Lecture Notes" (Vol. 1 and Vol. 2).
7. A. J. M. Spencer, "Continuum Mechanics," Dover Publishers, 1980.

Course Code	Course Name	L	T	P	Credits
ME502	Agricultural Machinery	3	0	0	3

Credit: 3
Contact Hours (L-T-P): 3-0-0

Overlaps with: Nil
Couse Assessment Method: Tutorials, Quizzes, Projects, and Written Exams

Course Objective
The aim of the course is to impart comprehensive knowledge on Farm Machinery, emphasizing their pivotal role in enhancing agricultural production. Covering various operations from soil preparation to crop harvesting, including specialized equipment for different crops, irrigation, protection, and transportation, the course equips students with the skills needed for effective and modern agricultural practices.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the role of farm machinery in enhancing agricultural productivity, addressing labour scarcity, and supporting various cropping systems.
- **CO2.** Gain knowledge of the design, components, and operation of machinery used for soil preparation, seedbed preparation, sowing, planting, inter-cultivation, irrigation, crop harvesting, and crop protection.
- **CO3.** Discuss advanced technologies and equipment, such as variable rate fertilizer applicators, microprocessor-based herbicide applicators, and spraying devices, for efficient and precise crop management.
- **CO4.** Elucidate the machinery used for transportation, material handling, land drainage, reclamation, and estate maintenance in agricultural operations.
- **CO5.** Acquire practical knowledge of specialized machinery for harvesting root crops and horticultural crops.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H					M	M	L				M
CO2	H				H	M	M	L				M
CO3	H	L			H	M	M	L	M		L	M
CO4	H				H	M	M	L				M
CO5	H				H	M	M	L				M

Syllabus

Basics of Farm Machinery: Importance of farm machines in the contest of enhance production, multiple cropping, labour scarcity etc., Ploughing and first opening of the soil, the design and component details, Machinery of seedbed preparation operation.

Farm Equipment: Equipment for sowing and planting and inter cultivation, Variable Rate Fertilizer Applicator, Microprocessor Based Herbicide Applicator, Spraying etc., Equipment for irrigation

Crop Machinery: Machinery for crop harvesting design and operation, Root crop harvesting machinery, Machinery for horticultural crops, Equipment for crop protection and disease control

Auxiliary Farm Machinery: Machinery for transport and material handling, Machinery for land drainage, reclamation and estate maintenance

References/Text Material:

1. R. A. Kepner, R. Bainer, and E. L. Barger, "Principles of Farm Machinery," AVI Publishing, 2012.
2. T. P. Ojha and A. M. Michael, "Principles of Agricultural Engineering," Jain Brothers, 2018.
3. Culpin, "Farm Machinery," Wiley, 2013.
4. H. L. Bohn, "Farm Implements and Farm Machinery," Wiley, 2018.
5. F. Klocke, "Handbook of Farm, Dairy, and Food Machinery Engineering," CRC Press, 2019.
6. K. Ekinci, "Farm Machinery and Power," McGraw-Hill Education, 2017.
7. S. K. Chaudhary, "Farm Machinery and Equipment," New India Publishing Agency, 2019.
    A. Singh, "Farm Power and Machinery Management," CRC Press, 2020.
8. E. Tegler, "Farm Machinery Repair," Storey Publishing, 2019.
9. G. Wilson, "Farm Machinery and Equipment: Principles of Operation and Safety," Delmar Cengage Learning, 2016.

Course Code	Course Name	L	T	P	Credits
ME503	Biomechanics	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The course objective is to explore the application of mechanical principles to biological systems, focusing on understanding the mechanics of tissues and organs, and their interactions, to address biomedical challenges and advancements in healthcare.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Apply fundamental principles from mathematics, physics, chemistry, computing, engineering, and biology to solve biomedical and biotechnological problems.
- **CO2.** Understand the basic mechanical properties, interactions, and functions of bones, tendons, ligaments, muscle, joints, and cartilage
- **CO3.** Discuss mathematical models used in the analysis of biomechanical systems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	H							M			
CO3	H	H	H	H					M			

Syllabus

Introduction: Basics of rigid body mechanics, Newton's laws of motion, Equation of motion for rigid Body, solid mechanics, and fluid mechanics applied in biological system.

Anatomy and Physiology: Basic introduction to anatomy and physiology; Mechanics of Human Motion; Mechanics of response of tissues including bones; Mechanics of Blood flow, Biosolidfluid interaction.

Biomechanics: Basic Introduction to biomechanics of tissue/cells, concept of Length Scale, Mechanical Forces, Mass, Stiffness and Damping of Proteins, Thermal Forces and Diffusion, Chemical Forces

Measurement techniques: Measuring techniques for force, pressure distribution, acceleration, Optical methods, strain measurement, inertial properties of human body.

Modeling: General considerations for modeling, types of model, validation of model, force system analysis, assumptions, free body diagrams, Simulation, Numerical solution methods, Muscle models, modeling of external forces, optimization studies, case studies.

Tissue Mechanics: Cell-cell Assemblies, Tissue Material Behavior, Introduction to Linear Viscoelasticity, Concept of Constitutive Modeling, Nonlinear continuum frame work of biomechancial simulation, special topic on tissue-device interaction, orthopedic/spinal implants etc.

Intracellular Mechanics: Structures of Cytoskeleton Filaments, Dynamics of Cell Filaments, Molecular motors, Introduction to Entropic Elasticity and Persistence Length, Force Generation by Cytoskeleton Filaments.

Extracellular Mechanics: The Extracellular matrix (ECM), cell-ECM Interactions, Cell Migration, Forces and Adhesion. Experimental Part Different Experimental Methods for Probing Cell & Tissue Mechanical Properties. Intro to Indentation, Aspiration, twezeer.

Cardiovascular and Respiratory Mechanics: Cardiovascular system, artificial heart valves, biological and mechanical valves development, lung ventilation model, methods of determining pressure, flow rate and volume spirometry.

References/Text Material:

1. R. Huston, "Principles of Biomechanics," 1st ed. CRC Press, 2008.
2. S. J. Hall, "Basic Biomechanics," 6th ed. McGraw-Hill Publishing Co., New York, 2012.
3. V. M. Zatsiorsky, "Kinematics of Human Motion," Human Kinetics Publishers, 1998.
4. V. M. Zatsiorsky, "Kinetics of Human Motion," Human Kinetics Publishers, 2002.
5. Zatsiorsky and Prilutsky, "Biomechanics of Skeletal Muscles," Human Kinetics Publishers, 2012.
6. A. M. Nigg and W. Herzog, "Biomechanics of Musculoskeletal System," John Wiley & Sons, 1st ed.
7. W. L. Saltzman, "Biomedical Engineering: Bridging Medicine and Technology," Cambridge Text, 1st ed.
8. A. Winter, "Biomechanics and Motor Control of Human Movement," Wiley Interscience, 2nd ed.

Course Code	Course Name	L	T	P	Credits
ME504	**Continuum Mechanics**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course objective is to introduce students to the principles of continuum mechanics, emphasizing the mathematical modeling and analysis of deformable bodies, fluid flow, and the relationships between stress, strain, and material behavior.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the kinematics of a continuum including concepts like deformation, strain, strain gradient, vorticity, etc.
- **CO2.** Understand the balance laws of continuum physics and the ability to express them in mathematical terms.
- **CO3.** Comprehend typical forms of constitutive behavior (elasticity, plasticity, creep, Newtonian and non-Newtonian fluids, etc.) and the ability to design new constitutive laws

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H			M					M			
CO3	H	H	M						M			

Syllabus

Introduction: Concept of continuum, introduction to some basic mathematical preliminaries, vectors and second order tensors, Tensor operation, Properties of tensors, Transformation of tensors, Invariants, eigenvalues and eigenvectors of second order tensors, Tensor fields, Differentiation of tensors, gradient operators and integral theorems.

Kinematics of deformation: Particle kinematics in both lagrangian and eulerian framework, Mapping and deformation gradients, material and spatial representations, Nanson's formula, Strain measures, Rotation & stretch tensors, rate of deformation

Stress Tensors: Concept of Cauchy-stress tensor, their transformation and decomposition, first and second Piola- Kirchoff's & Cauchy's stress tensors, principal stresses, normal and shear stresses, principle stresses with examples.

Strain tensor: Lagrangian and eulerian strain tensor, infinitesimal strain tensor, normal and shear strains in both finite and infitesimal cases with examples, compatibility conditions, rate of deformation gradient – velocity gradient and spin tensor.

Conservation Laws: Derivation – mass continuity and angular momentum balance, derivation of linearized equations of elasticity and Navier stokes equations in both Cartesian and polar co-ordinates, Continuum thermodynamics, Clausius-Duhem inequality, Frame dependent and independent quantities, Objective rates.

Constitutive laws: Laws for linearly elastic solids and Newtonian viscous fluids, Principle of minimum potential energy, virtual work theorem, uniqueness and reciprocal theorem, generalized Hooke's law, material symmetry, visco-elasticity, metal plasticity: Yield criteria, Flow rule, Hardening rule, loading & unloading conditions, multiplicative strain decomposition, rheological models

Solid mechanics application: Plane stress/plane strain problems, bending and twisting of circular shafts, stress based formulation (airy stress function), displacement potential function.

Fluid mechanics application: Integral flow analysis, Reynolds transport theorem, Bernouli equations and exact solutions, Boundary layer concept and equations.

References/Text Material:

1. A.J.M. Spencer, "Continuum Mechanics," Dover Publishers, 1980.
2. Michael Lai, Erhard Krempl, David Ruben, "Introduction to Continuum Mechanics," Fourth Ed..
3. G. A. Holzapfel, "Nonlinear solid mechanics, vol. 24," Chichester, New York, 2000.
4. C. S. Jog, "Continuum Mechanics: Foundations and Applications of Mechanics, Volume-I," Third Ed., Cambridge-IISc Series, Cambridge University Press, 2015.
5. B. Tadmor, R. E. Miller, and R. S. Elliot, "Continuum Mechanics and Thermodynamics: From Fundamental Concepts to Governing Equations," Cambridge University Press, 2012.
6. W. M. Lai, D. Rubin, and E. Krempl, "Introduction to Continuum Mechanics," Butterworth-Heinemann, 4th Ed., 2015.
7. F. Bower, "Applied Mechanics of Solids," CRC Press, 2010. Website: http://solidmechanics.org/
8. T. Mase and G. E. Mase, "Continuum Mechanics for Engineers," CRC Press, 2nd Ed., 1999.

Course Code	Course Name	L	T	P	Credits
ME505	Dynamics of Mechanical Systems	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**

Overlaps with: **Nil**
Course Assessment Method: **Tutorials, Quizzes, and Written Exams**

Course Objective

The aim of this course is to furnish students with a comprehensive understanding of mechanical system dynamics. Covering fundamental laws of motion, Lagrangian dynamics, multi-body dynamics, stability analysis, and control system dynamics, the course enables students to analyze and model the behavior of mechanical systems. Emphasizing key concepts like generalized coordinates, Euler angles, and stability criteria, students gain the skills to address complex dynamic problems in mechanical engineering.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the fundamental principles of dynamics, including laws of motion, conservation principles, and work-energy principles, and their application to mechanical systems.
- **CO2.** Gain proficiency in Lagrangian dynamics, including the formulation of Lagrange's equations, handling holonomic and non-holonomic constraints, and applying them to conservative and non-conservative systems.
- **CO3.** Explain multi-body dynamics, including coordinate systems, transformations, angular velocity and acceleration, equations of motion, and analysis of planar kinematics and dynamics.
- **CO4.** Discuss the stability in mechanical systems, including stability analysis using phase plane plots, Routh's criteria, and Liapunov's method.
- **CO5.** Elucidate the basics of control system dynamics, including open and closed-loop systems, block diagrams, transfer functions, and the characteristics of proportional integral and derivative control actions.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H											
CO2	H	H	H									
CO3	H		M	H								
CO4	H	H	H									
CO5	H	H	H									

Syllabus

Basic concepts: Inertial coordinate system, fundamental laws of motion, mechanics of particles and system of particles, principles of linear and angular momentum, work-energy principles.

Lagrangian dynamics: Degrees of freedom, generalized coordinates and generalized forces, holonomic and non-holonomic constraints, Lagrange's equation from d'Alembert's principles, application of Lagrange's equation for conservative and non-conservative autonomous systems with holonomic and non-holonomic constraints, applications to systems with very small displacements and impulsive motion; Hamilton principle from d'Alembert's principle, Lagrange equation from Hamilton's principle.

Multi-body dynamics: Space and fixed body coordinate systems, coordinate transformation matrix, direction cosines, Euler angles, Euler parameters, finite and infinitesimal rotations, time derivatives of transformations matrices, angular velocity and acceleration vectors, equations of motion of multi-body system, Newton-Euler equations, planer kinematic and dynamic analysis, kinematic revolute joints, joint reaction forces, simple applications of planer systems.

Stability of motion: Fundamental concept in stability, autonomous systems and phase plane plots, Routh's criteria for stability, Liapunov's method, Liapunov's stability theorems, Liapunov's function to determine stability of the system.

Control system dynamics: Open and close loop systems, block diagrams, transfer functions and characteristics equations, proportional integral and derivative control actions and their characteristics.

References/Text Material:

1. J. H. Ginsberg, "Advanced Engineering Dynamics," Harper and Row, 1988.
2. L. Meirovitch, "Methods of Analytical Dynamics," McGraw Hill Inc., 1970.
3. H. Josephs and R. Huston, "Dynamics of Mechanical Systems," CRC Press, 2002.
4. K. Ogata, "System Dynamics," 4th Ed., Prentice Hall, 2003.
5. R. L. Woods and K. L. Lawrence, "Modeling and Simulation of Dynamic Systems," Prentice Hall, 1997.
6. R. S. Esfandiari and B. Lu, "Modeling and Analysis of Dynamic Systems," CRC Press, 2010.
7. A. C. Karnopp, D. L. Margolis, and R. C. Rosenberg, "System Dynamics: Modeling and Simulation of Mechatronic Systems," 4th Ed., Wiley, 2006.
8. R. A. Layton, "Principles of Analytical System Dynamics (Mechanical Engineering Series)," Springer.
9. M. Geradin and D. J. Rixen, "Mechanical Vibrations: Theory and Application to Structural Dynamics," 3rd Ed, Wiley, 2015.
10. C. T. F. Ross, "Dynamics of Mechanical Systems," Wiley, 1997.
11. N. J. Kasdin and D. A. Paley, "Engineering Dynamics – A Comprehensive Introduction," Princeton University Press, 2011.
12. A. Ghosh and A. K. Mallik, "Theory of Mechanics and Machines," East West Pub., 2008.

Course Code	Course Name	L	T	P	Credits
ME506	Fatigue in Design	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The aim of the course is to emphasize the importance of fatigue considerations in design and to explore strategies for fatigue design

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand mechanical failure modes
- **CO2.** Analyse fatigue fracture surfaces, macroscopic features, and underlying fatigue mechanisms
- **CO3.** Utilize knowledge of stress-life and strain-life curves
- **CO4.** Discuss linear and nonlinear damage theories

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	M							M			
CO2	H	H		H					M			
CO3	H	M		M					M			
CO4	H	M		M			M		M			

Syllabus

Introduction: Mechanical failure modes, importance of fatigue considerations in design, strategies in fatigue design, fatigue design criteria, fatigue fracture surfaces and macroscopic features, fatigue mechanisms.

Fatigue Tests and Stress-Life Approach: Fatigue loading, stress-life (S-N) curves, mean stress effects on S-N behavior, factors influencing S-N behavior, notches and their effects.

Cyclic Deformation and Strain-Life Approach: Monotonic and cyclic stress-strain behavior, strain-life curve, factors influencing strain-life behavior.

Fatigue from Variable Amplitude Loading: Variable amplitude loading, linear and nonlinear damage theories, cycle counting, crack propagation under variable amplitude loading.

Environmental Effects: Corrosion fatigue, fretting fatigue, low-temperature fatigue, high-temperature fatigue.

References/Text Material:

1. R. I. Stephens, A. Fatemi, R. R. Stephens, and H. O. Fuchs, "Metal Fatigue in Engineering," John Wiley & Sons, 2000.
2. J. A. Bannantine, J. J. Comer, and J. L. Handrock, "Fundamentals of Metal Fatigue Analysis," Prentice Hall, Upper Saddle River, NJ, 1990.

3. J. A. Collins, "Failure of Materials in Mechanical Design: Analysis, Prediction, Prevention," John Wiley & Sons, 1993.
4. S. Suresh, "Fatigue of Materials," Cambridge University Press, 1998.

Course Code	Course Name	L	T	P	Credits
ME507	Fracture Mechanics	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The course objective is to provide a comprehensive understanding of the principles and methodologies of fracture mechanics, focusing on the analysis of crack initiation, propagation, and failure in materials and structures.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the mechanism of fracture in brittle and ductile materials.
- **CO2.** Learn mechanics of crack tip fields and appropriate fracture characterizing parameters like stress intensity factor and J integral or nonlinear energy release rate and how to compute them using various methods.
- **CO3.** Apply the concepts learnt to design structural components taking into account presence of flaws, nature of loading and constitutive behavior of the material.
- **CO4.** Conduct experiments in the laboratory to determine the fracture toughness of materials

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	H							M			
CO3	H	H	H	H					M			
CO4	H	H		M					M			

Syllabus

Introduction: Background, failure of structures, bridges, pressure vessels and ships, brittle fracture, Introduction to the realm of fracture and back ground history of development of fracture mechanics; Discrepancy between theoretical and real strength of materials, conventional failure criteria based on stress concentration and characteristic brittle failures, Griffith theory of fracture, energy release rate (ERR), conditions for stable and unstable crack growth, crack arrest.

Linear elastic fracture mechanics: Crack deformation modes and basic concepts, crack tip stresses and deformation, Williams analysis of stress field at the tip of a crack,
Solution of stress and displacement field for plane cracks using complex methods in plane elasticity (Westergaards or Kolosov-Muskhelishvili approach), Stress intensity factor (SIF) for plane and penny shaped cracks, Equivalence of SIF and ERR, fracture toughness.

Elasto-plastic fracture mechanics: First order estimate of crack tip plastic zone using Irwin's and Dugdle's approach, Plastic zone for plane stress and plane strain situation and effect on fracture toughness, Review of small strain plasticity, Crack tip fields in an Elasto-plastic material (Discussion on HRR fields), J-integral as a fracture parameter and crack growth resistance (R curve) concepts.

Mixed mode fracture: Prediction of crack path and critical condition for crack extension under mixed mode loading using Maximum tensile stress, Minimum strain energy density and Maximum energy release rate criteria.

Experimental measurement of SIF and fracture toughness: SIF measurement using strain gages, optical techniques, Evaluation of fracture toughness

Fatigue crack growth: Mechanism of crack nucleation and growth under cyclic loading, Determination of life of a cracked solid using Paris-Erdogan law and its variants

Advanced topics: Computational fracture mechanics, Dynamic fracture, Bi-material fracture

References/Text Material:

1. C.T. Sun and Z.H. Jin, "Fracture Mechanics," Academic Press, 2011.
2. T.L. Anderson, "Fracture Mechanics," CRC Press, 2017
3. E.E. Gdoutos, "Fracture Mechanics An Introduction," Springer Nature, 2020
4. P.Kumar, "Elements of Fracture Mechanics", McGraw Hill, 2012.
5. M. Jansen, J. Zuidema, R. Wanhill, "Fracture Mechanics" Spon Press, 2004.
6. T.L. Anderson, "Fracture Mechanics: - Fundamentals and Application", Taylor and Francis, 2005.
7. R.W. Hetzberg, "Deformation and fracture mechanics of engineering material", John wiley and son, 1996.
8. T. L. Anderson, "Fracture Mechanics-Fundamentals and Applications", 3rd Ed., CRC Press, 2005
9. Prashant Kumar, "Elements of Fracture Mechanics", McGraw Hill Education (India) Pvt., Ltd, New Delhi, 2014

Course Code	Course Name	L	T	P	Credits
ME508	Machinery Fault Diagnosis	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

To provide a comprehensive understanding of machinery condition monitoring, covering the principles of maintenance (reactive, preventive, and predictive).

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Demonstrate a profound understanding of machinery condition monitoring principles
- **CO2.** Master techniques for vibration monitoring and analysis
- **CO3.** Apply thermography for effective condition assessment
- **CO4.** Employ advanced methods in condition monitoring

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H	M						M			
CO2	H	M			M				M			
CO3	H	H							M			
CO4	H	H	M	H					M			

Syllabus

Basic Concepts: Need for machinery condition monitoring, principles of maintenance: reactive maintenance, preventive maintenance, and predictive maintenance, failure modes effects and criticality analysis.

Vibration monitoring: Principles, misalignment detection, eccentricity detection, cracked shaft, bowed and bent shaft, unbalanced shaft, looseness, bearing defects, gear fault.

Thermography: Introduction, thermal imaging devices, leakage detection, electrical and electronic component heat generation.

Wear debris analysis: Mechanisms of wear, detection of wear particles: spectroscopy, ferrography, and particle count, oil sampling technique, oil analysis, limits of oil analysis.

Machine tool condition monitoring: Tool wear, sensors for tool condition monitoring: direct and indirect tool wear measurements.

Electrical machinery faults: Construction of an electric motor, faults in electric motor, fault detection in electric motors, motor current signature analysis for fault detection: broken rotor bar, eccentricity related faults, and bearing faults, instrumentation for motor current signature analysis, fault detections in submersible pump, power supply transformers, switchgear devices.

Other methods in condition monitoring: Introduction, eddy current testing, ultrasonic testing, radiography, acoustic emission.

References/Text Material:

1. A. R. Mohanty, "Machinery Condition Monitoring: Principles and Practices," CRC Press, 2014.
2. A. Davies, "Handbook of Condition Monitoring: Techniques and Methodology," Springer Science & Business Media, 2012.
3. A. Hand, "Electric Motor Maintenance and Troubleshooting," McGraw Hill Professional, 2011.
4. R. D. Whitby, "Lubricant Analysis and Condition Monitoring," CRC Press, 2021.

Course Code	Course Name	L	T	P	Credits
ME509	**Synthesis of Mechanisms**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **Tutorials, Quizzes, Programming Assignments, projects, and Written Exams**

Course Objective

The aim of the course is to provide students with a profound understanding of kinematic synthesis. Covering mechanisms, degree of freedom, position and function generation problems, the course explores Harding's notation, Grashof and Grubler's criteria, matrix methods, and graphical synthesis. Additionally, it delves into accuracy considerations, path generation, spatial mechanisms, and their applications, offering students a comprehensive foundation for practical engineering synthesis.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Develop a comprehensive understanding of kinematics and the types of mechanisms, including their practical applications.
CO2. Gain proficiency in kinematic synthesis techniques for position and function generation problems, including the use of matrices, graphical methods, and complex number methods.
CO3. Acquire knowledge of error analysis and optimization techniques for ensuring accuracy and optimal performance in mechanism design.
CO4. Illustrate techniques of path generation in mechanisms, including the synthesis of coupler curves and the application of complex number methods.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H											
CO2	H	H	H									
CO3	H	M	H									
CO4	H	H	M	H								

Syllabus

Introduction to Mechanisms: Kinematics, types of mechanism, kinematics synthesis, science of relative motion, tasks of kinematic synthesis with practical applications, Degree of freedom, class-I, class-II chain, Harding's notation, Grashof criterion, Grubler's criterion. Introduction to position generation problem, concept of pole, two & three position generation synthesis, pole triangle, Relationship between moving & fixed pivots, Four-position generation, opposite pole quadrilateral, center point & circle point curve, Burmester's point. Matrix method for position generation problem, rotation matrix, displacement matrix.

Techniques of Mechanism Synthesis: Introduction to function generation problem, coordination of input-output link motion, relative pole technique, inversion technique, overlay technique, graphical synthesis of quick return mechanisms for optimum transmission angle.

Types of errors, accuracy points Chebyshev’s spacing and Freudenstein’s equation. Introduction to path generation problem, synthesis for path generation with and without prescribed timing using graphical method. Coupler curves, cognate linkages, Robert's law of cognate linkages. Complex number method for path generation problem 3 precision point. Synthesis for infinitesimally separated position, concept of polode and centrode, Euler's savery equation, inflection circle, Bobbilier and Hartman's construction. Optimal synthesis of planer mechanisms, least square method. Introduction to spatial mechanisms, D-H notations, Introduction to kinematic analysis of robot arms.

References/Text Material:

1. R. L. Norton, "Design of Machinery – An Introduction to the Synthesis and Analysis of Mechanisms and Machines," 6th Ed, McGraw Hill, 2020.
2. S. S. Rattan, "Theory of Machines," 4th Ed, McGraw Hill, 2017.
3. G. Erdman, G. N. Sandor, S. Kota, "Mechanism Design - Analysis and Synthesis," Vol. I, 4th Ed, Prentice Hall, New Jersey, 2001.
4. G. N. Sandor, A. G. Erdman, "Advanced Mechanism Design - Analysis and Synthesis," Vol. II, Prentice Hall, 1984.
5. G. Suh, C. W. Radcliff, "Kinematics and Mechanisms Design," John Wiley & Sons, 1978.
6. H. Soni, "Mechanism Synthesis and Analysis," McGraw Hill, 1984.

Course Code	Course Name	L	T	P	Credits
ME510	Tribology	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

To provide a comprehensive understanding of interacting engineering surfaces in relative motion and associated concepts.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the fundamental concepts of tribology
- **CO2.** Apply knowledge of surface topography and contact mechanics
- **CO3.** Understand friction, wear, and lubrication science
- **CO4.** Get exposure to emerging trends in the tribology field

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	H		M	M				M			
CO3	H	M		M			M		M			
CO4	H	H		H			M		M			

Syllabus

Introduction: Definition and scope of tribology, historical background and importance of tribology, tribological challenges in engineering applications.

Surface topography and contact mechanics: Surface roughness and characterization techniques, contact mechanics and Hertzian contact theory, elastic and plastic deformation in contacting surfaces.

Friction: Types of friction: dry friction, boundary friction, and fluid friction, friction laws and coefficients, factors influencing frictional behavior.

Wear: Types and mechanisms of wear: adhesive, abrasive, erosive, and fatigue wear, wear testing methods and characterization techniques, wear modeling and prediction.

Lubrication: Fundamentals of lubrication: viscosity, pressure-viscosity relationship, and lubricant additives, hydrodynamic lubrication and Reynolds equation, boundary lubrication and thin-film lubrication.

Tribocorrosion: Introduction to tribocorrosion phenomena, electrochemical aspects of tribocorrosion, corrosion-wear interactions.

Tribological systems and applications: Bearings and lubrication systems, gears and gear lubrication, sliding and rolling contact systems, cutting and machining processes.

Experimental techniques in tribology: Tribological test methods: pin-on-disk, ball-on-disk, and wear testing machines, surface characterization techniques: profilometry, microscopy, and spectroscopy, analysis and interpretation of experimental results.

Emerging trends in tribology: Nanotribology, biotribology, coatings, green tribology.

References/Text Material:

1. B. Bhushan, "Introduction to Tribology," John Wiley & Sons, 2013.
2. G. Stachowiak and A. W. Batchelor, "Engineering Tribology," Butterworth-Heinemann, 2013.
3. G. Hutchings and P. Shipway, "Tribology: Friction and Wear of Engineering Materials," Butterworth-Heinemann, 2017.
4. S. K. Basu, S. N. Sengupta, and B. B. Ahuja, "Fundamentals of Tribology," PHI Learning Pvt. Ltd., 2005.
5. P. Sahoo, "Engineering Tribology," PHI Learning Pvt. Ltd., 2005.

Course Code	Course Name	L	T	P	Credits
ME511	Automation Technologies	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

This comprehensive course aims at introducing automation, equipping the student with the knowledge and skills to design, build, and program intelligent machines. Students will be exposed to sensor technology, understand machine vision, and explore the intricate workings of robots, from their physical components to dynamic modeling and advanced programming.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Develop a comprehensive understanding of automation technologies, including its definitions, principles, and applications.
- **CO2.** Explore the role of control systems in automation, including concepts, analysis, and design.
- **CO3.** Gain practical knowledge of sensors and their integration in automation systems, including vision, range sensing, touch sensing, and signal conditioning.
- **CO4.** Understand the fundamentals of robotics, including robot configurations, subsystems, actuation mechanisms, and end effectors.
- **CO5.** Acquire programming skills for robots, including knowledge of programming languages, control methods, and the use of artificial intelligence in automation.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	M	H	H					H			
CO2	H	M	H	H					M			
CO3	H	M	M	H	H				M			H
CO4	H	H	M	M	H				M			
CO5	H	H	H	H	H				M			H

Syllabus

Introduction to automation: basic notions and definitions, technical and economic requisites. Automation as a means of control and inspection, basic control system concepts, control system analysis, systems of automatic control.

Sensors: sensory equipment, range sensing, proximity sensing, touch sensing, force and torque sensing, signal conditioning equipment. Vision, ranging, laser, acoustic, tactile sensors. Developments in sensor technology, sensory control.

Introduction to machine vision: sensing and digitizing, image processing and analysis, applications.

Introduction to robots: brief history, basic concepts, trends in robotics, overview of robot subsystems, challenges in robotics, characteristics of robots, robot configurations and concept of work space, types of actuators and sensors in robotics, types of grippers, types of robot drives, basic robot motions - point to point control, continuous path control, manipulators – director and inverse kinematics, coordinate transformation, brief robot dynamics. Components and operations, basic actuation mechanisms, Types and applications of robot and effectors, grippers, tools as end effectors.

Dynamic modeling: Lagrangian formulation, examples, trajectory generation: general consideration in path description and generation, joint space schemes, collision free path planning; robot control.

Robot programming: Methods, languages, capabilities and limitation, artificial intelligence, Knowledge representation, search techniques, Programming Language: VAL, RAIL, AML. Mobile robots, AI and robotics. Some Industrial applications of robots.

References/Text Material:

1. K. S. Fu, R. C. Gonalez, and C. S. G. Lee, "Robotics Control Sensing, Vision and Intelligence," McGraw Hill International Ed., 1987.
2. M. P. Groover and M. Weiss, "Industrial Robotics, Technology, Programming, and Applications," McGraw Hill International Ed.s, 1986.
3. R. D. Klafter, T. A. Chmielewski, and M. Negin, "Robotic Engineering – An Integrated Approach," Prentice Hall Inc., 1989.
4. R. K. Mittal and I. J. Nagarath, "Robotics and Control," Tata McGraw Hill, 2003.
5. S. B. Niku, "Introduction to Robotics: Analysis, Systems and Applications," 2nd ed., Prentice Hall India, 2010.
6. M. W. Spong and M. Vidyasagar, "Robot Dynamics and Control," John Wiley & Sons, 1989.
7. R. P. Paul, "Robot Manipulators: Mathematics, Programming, Control," The MIT Press, 1979.
8. R. J. Schilling, "Fundamentals of Robotics: Analysis and Control," Prentice Hall of India, 1996.

Course Code	Course Name	L	T	P	Credits
ME512	**Composite Materials**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course objective is to familiarize students with the properties, fabrication, analysis, and applications of composite materials, emphasizing their unique characteristics and structural performance in various engineering fields.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand behavior and specialties of orthotropic materials.
- **CO2.** Find appropriate applications where a particular composite can be used.
- **CO3.** Understand types of manufacturing processes, and applications of composite materials.
- **CO4.** Compare various theories of failure for composite materials.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	H	H	H					M			
CO3	H	H	H						M			
CO4	H	H	H						M			

Syllabus

Introduction to Composites: Definition, General characteristics of composite materials, Classification, Fibrous, laminated and particulate composites, Advantages, Disadvantages and Applications of fibre reinforced composites

Fibre Materials: Natural fibres, Glass fibres, Carbon Fibres, Aramid Fibres, Boron fibres, Ceramic Fibres and their manufacturing, Surface Modification of fibres.

Matrix materials: Polymer matrices –Thermoplastic and thermosetting matrix materials, Unique Characteristics of Polymeric Solids, Creep and Stress Relaxation, Heat Deflection Temperature

Incorporation of fibres into matrix – Prepregs and Sheet Moulding Compounds (SMC), Advantages and disadvantages of polymer matrix composites, metal matrix composites and ceramic matrix composites

FRC Manufacturing: Fundamental concepts: Degree of Cure, Viscosity, Resin Flow, Consolidation, Gel-time Test, Shrinkage, Voids

Typical Manufacturing Processes: Hand Lay-Up Process, Spray-Up Process, Autoclave Moulding, Resin Transfer Moulding, Reaction Injection Moulding, Filament Winding, Pultrusion, Compression Moulding; Manufacturing Processes for Thermoplastic Matrix Composites,

Quality Inspection Methods: Raw Materials, Cure Cycle Monitoring, Cured Composite Part - Radiography, Ultrasonic, Acoustic Emission, Acousto-Ultrasonic, Thermography

Mechanics of FRC: Fiber-Matrix Interactions in a Unidirectional Lamina, Longitudinal and Transverse Loading of Unidirectional Continuous and Discontinuous Fibres reinforced Composites, Empirical relationship of Halpin-Tsai. Longitudinal and transverse Strength. Composites under compressive loading

Characteristics of a Fiber-Reinforced Lamina – Fundamentals, Coordinate Axes, Notations, Stress and Strain Transformations in a Thin Lamina under Plane Stress, Isotropic, Anisotropic, and Orthotropic Materials

Elastic Properties of a Lamina: Stress–Strain Relationships for a Thin Lamina, Codes and engineering representation of Laminates. Macro mechanical behavior of a laminate. Laminate stiffness for different types; symmetric, anti-symmetric, cross ply laminates. Stresses in different laminate in a laminate. Configurations and design of laminates for special properties Strength and mechanism of failure in a composite laminate. Concept of FPF (First Ply Failure and total failure). Hygroscopic and thermal stresses. Compliance and Stiffness Matrices (Derivations and Numericals)

Failure Prediction in a Unidirectional Lamina: Maximum Stress Theory, Maximum strain theory and Tsai-Wu Failure Theory. Applications to pressure vessels, composite shafts etc.

Mechanical Properties and Testing of FRCs: Tensile Properties, Compressive Properties, Flexural Properties, Impact Properties, Fracture, Fatigue and Creep Properties of FRCs

References/Text Material:

1. P. K. Mallick, Fiber Reinforced Composites, CRC Press, 3 rd Ed., 2007
2. Autar K. Kaw, Mechanics of Composite Materials, CRC Press LLC, 1997
3. Bhagwan D. Agarwal, Lawrence J. Broutman and K. Chandrashekhara, Analysis and Performance of Fiber Composites, 3rd Ed., Wiley India, 2012
4. Isaac M. Daniel and Ori Ishai, Engineering Mechancis of Composite Materials, 2nd Ed., Oxford University Press, 2013
5. Guneri Akovali, Handbook of Composite Fabrication, Rapra Technology Ltd, 2001
6. M. Balasubramanian, Composite materials and processing, CRC Press, 2014
7. Sanjay K. Mazumdar, Composites Manufacturing - Materials, Product, and Process Engineering, CRC Press, 2002
8. Mechanics of Composite Materials (Materials Science & Engineering Series) by Robert M Jones.
9. Principles of Composite Material Mechanics, Third Ed. (Mechanical Engineering) by Ronal F Gibson.
10. Broutman and Agarwal, "Analysis and Performance of Composite materials", John Willey and Sons, New York

Course Code	Course Name	L	T	P	Credits
ME513	**Design for Manufacturing and Assembly**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

This course aims to provide knowledge and training in using Design for assembly and manufacturing techniques and apply it to real case scenarios

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the design for manufacturing and assembly
- **CO2.** Gain knowledge on basic manufacturing and assembly processes
- **CO3.** Discuss the design consideration in assembly
- **CO4.** Illustrate the application of DFMA techniques

POs → / COs ↓	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	M	M	L	H	M	M	L	L			H
CO2	H				H	M	M					M
CO3	H	H	H	M	M	L						M
C04	H	H	H	L		M	M		H	H	L	M

Syllabus

Introduction to Design for manufacturing and assembly: Introduction, History of DFMA, Steps for applying DFMA during product design, Advantages of applying DFMA during product design, Reasons for not implementing DFMA

Introduction to Manufacturing Process: Classification of manufacturing process, Basic manufacturing processes, the assembly process, Characteristics and applications, Example of common assembly, Economic significance of assembly

Design for Assembly (DFA): Introduction to assembly, General taxonomies of assembly operation and systems, assembling a product, Design consideration in assembly, Various DFA techniques

Case Studies: Application of Boothroyd DFMA techniques to product design and comparison of other techniques

References/Text Material:

1. O. Molloy, S. Tilley, and E. A. Warman, "Design for Manufacturing and Assembly," Springer, 2012.
2. G. Boothroyd, P. Dewhurst, and W. A. Knight, "Product Design for Manufacture and Assembly," Marcel Dekker Inc, New York, 2010.
3. J. G. Bralla, "Design for Manufacturability," McGraw-Hill, 2004.

Course Code	Course Name	L	T	P	Credits
ME514	**Ergonomics**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

This course aims to understand knowledge in ergonomics practices and provide training to apply it for design of various systems effectively by the application of ergonomics concept.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Understand the methods and procedures in ergonomics
CO2. Design the man machine systems
CO3. Eliminate unnecessary work by understanding work ergonomics
CO4. Study the most effective procedures for performing work

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H		L	L					M			
CO2	H	H	H	H					M			
CO3	H	M	M	M					M			
CO4	H	H	M	M					M			

Syllabus

Introduction to Ergonomics: Ergonomics for productivity, safety, health and comfort, history of ergonomics, multi-disciplinary engineering

Human-machine system and display: Human-machine system -characteristics, information theory, coding, compatibility, memory, decision making, attention, text, graphics, symbols, selection of display modality -visual and auditory display, representational display, tactual and olfactory display, design of controls

Anthropometry: Need for anthropometry, sources of human variability, data collection methodology, measuring procedures and tools, statistical analysis of measured data -percentile calculation, principles of applied anthropometry, applications of anthropometry

Work Ergonomics: Work station design for standing and seated workers, manual material handling, design of hand tools, muscles, structure, function and capacity, physical work capacity, measurement of physiological work, stress and fatigue, work-related musculoskeletal disorders, ergonomic interventions to prevent injuries, human thermoregulation, measurement, protection and thermal comfort

Vision, Noise and Vibration: Vision and the eye, measurement of light, lighting design, visual fatigue, eyestrain, psychological aspects of indoor lighting, the ear, measurement of sound, ear protection, design of acoustic environment, industrial noise control, auditory environment outdoors, effects of noise on task performance and health, vibration, human error, safety and equipment design

References/Text Material:

1. R. S. Bridger, "Introduction to Human Factors and Ergonomics," CRC Press, Taylor and Francis Group, 2017.
2. M. Helander, "A Guide to Human Factors and Ergonomics," CRC Press, Taylor and Francis Group, 2005.
3. M. S. Sanders, "Human Factors in Engineering and Design," McGraw Hill Education, 2013.
4. C. Nemeth, "Human Factors Methods for Design," CRC Press, Taylor and Francis Group, 2004.
5. D. Chakrabarti, "Indian Anthropometric Dimensions for Ergonomic Design Practice," National Institute of Design, Ahmedabad, 1997.
6. V. G. Duffy, "Handbook of Digital Human Modelling: Research for Applied Ergonomics and Human Factor Engineering," CRC Press, Taylor and Francis Group, 2009.

Course Code	Course Name	L	T	P	Credits
ME515	**Introduction to Additive Manufacturing**	**3**	**0**	**0**	**3**

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The course aims to provide a comprehensive understanding of additive manufacturing, covering its historical development, classifications, data processing, and various solid, liquid, and powder-based systems. Students will gain insights into the principles, processes, materials, and applications of additive manufacturing, along with an introduction to its impact on product development and rapid tooling.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to –

- **CO1.** Understand the fundamentals of various Additive Manufacturing technologies for application to various industrial needs.
- **CO2.** Convert part file into STL format.
- **CO3.** Illustrate the method of manufacturing liquid based, powder based andsolid based techniques.
- **CO4.** Discuss the manufacturing procedure of a prototype using FDM technique.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	L							M			
CO2	H	H		M	H				M			
CO3	H	M	H	H					M			
CO4	H	M	H	L					M			

Syllabus

Introduction and Classification of additive manufacturing: Fundamentals of Additive Manufacturing (AM), historical development of AM, classifications of AM systems, information workflow in AM, impact of AM on product development, reverse engineering, digitization techniques, model construction

Data processing for additive manufacturing: Additive Manufacturing data formats, STL Format, STL file problems, consequences of building a valid and invalid tessellated model, STL file repair, other translators, newly proposed formats standard for representing layered manufacturing objects

Solid and liquid based additive manufacturing systems: Fused Deposition Modelling, Laminated Object Manufacturing (LOM), Stereolithography (SLA), Solid Ground Curing (SGC), Shape Deposition Manufacturing (SDM), JP-System, poly jet printing, principle, details of processes, process variables, types, products, materials, advantages and applications

Powder based and other additive manufacturing systems: Selective Laser Sintering (SLS), Selective Laser Melting (SLM), Electron Beam Melting (EBM), powder based beam deposition processes, printing processes, Three-Dimensional Printing(3DP), droplet formation technology, printing process modelling, principle, details of processes, process variables, types, products, materials, advantages and applications

Applications and Rapid Tooling: Applications of AM in various industries, Introduction to rapid tooling

References/Text Material:

1. I. Gibson, D. W. Rosen, B. Stucker, "Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing," Springer, 2015.
2. G. W. Liou, "Rapid Prototyping and Engineering Applications: A Tool Box for Prototype Development," CRC Press, 2019.
3. C. K. Chua, K. F. Leong, C. S. Lim, "Rapid Prototyping: Principles and Applications," World Scientific Publishers, 2010.
4. P. D. Hilton, P. F. Jacobs, "Rapid Tooling: Technologies and Industrial Applications," CRC Press, 2011.
5. D. T. Pham, S. S. Dimov, "Rapid Manufacturing," Verlag, 2011.
6. P. F. Jacobs, "Rapid Prototyping and Manufacturing," ASME Press, 1996
7. G. Gibson, D. Rosen, B. Stucker, "Additive Manufacturing Technologies," Springer, 2014.

Course Code	Course Name	L	T	P	Credits
ME516	Industrial Robotics	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
This comprehensive course introduces the students to Industrial Robotics and their diverse types and capabilities, from material handling to welding and assembly. It also aims to explore cutting-edge sensors and control systems that guide every movement, and learn to program the robots using specialized languages like VAL and RAIL.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to –

CO1. Understand the various robot structures and fundamental concepts in CAM, CIMS, Robots
CO2. Acquire skills in performing spatial transformations associated with rigid body motions
CO3. Perform kinematics analysis of robot systems through NC part programming, APT programming and Robot programming
CO4. Explain the singularity issues associated with the operation of robotic systems such as sensors, actuators

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H			L					M			
CO2	H	M		H	M				M			
CO3	H	H	M	H	H				M			
CO4	H	L		H					M			

Syllabus

Types of industrial robots: Load handling capacity, general considerations in Robotic material handling, material transfer, machine loading and unloading, CNC machine tool loading, Robot centered cell.

Sensors, Actuators, and Control: Construction of manipulators, advantages and disadvantages of various kinematic structures. Pneumatic, hydraulic and electric. Robotic vision systems, image representation, object recognition and categorization, depth measurement, image data compression, visual inspection, software considerations. Characteristics and control. Nonservo robots, motion planning. Feedback systems, encoders, servo control PTP and CP.

Application of Robots: Continuous arc welding, Spot welding, Spray painting, assembly operation, cleaning, robot for underwater applications. Gripper force analysis and gripper design, design of multiple degrees of freedom, active and passive grippers. Manipulator dynamics and force control. Vision, ranging, laser, acoustic, tactile. Developments in sensor technology, sensory control.

Selection of a robot: Factors influencing the choice of a robot, robot performance testing, economics of robotisation, Impact of robot on industry and society.

Programming Language: VAL, RAIL, AML. Mobile robots, walking devices.

References/Text Material:

1. K. S. Fu, R. C. Gonzalez, C. S. G. Lee, “Fundamental of Robotics”, McGraw Hill, 1987
2. Y. Koren, “Robotics for Engineers”, McGraw Hil, 1985
3. A. Ghosal, “Robotics-Fundamental Concepts and Analysis”, Oxford University Press. 2013
4. J. J. Craig, “Robotics”, Addison Wesley, 1986
5. R. D. Klafter, T. A. Chmielewski, M. Negin, “Robotic Engineering – An integrated Approach” Prentice Hall India, New Delhi, 2001
6. M. P. Groover, “Automation, Production Systems, and Computer Integrated Manufacturing” Pearson, 2013
7. J. A. Rehg, “Introduction to Robotics in CIM Systems”, Prentice Hall, India, 2002
8. S. R. Deb, “Robotics Technology and Flexible Automation”, TMH, New Delhi, 2010

Course Code	Course Name	L	T	P	Credits
ME517	Mechatronics	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The course on Mechatronics aims to discuss its mechanics, electronics, and software. It equips the student with the expertise to design, build, and control intelligent machines. It also aims to explore sensors and actuators, digital electronics and signal conditioning, and also introduce PLC programming.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Develop a solid understanding of Mechatronics and its applications in automation, manufacturing, and product development.
- **CO2.** Study sensors and feedback devices in Mechatronics, including their importance, characteristics, and measurement capabilities.
- **CO3.** Learn about control elements and actuators, such as switches, relays, mechanical and electrical actuators, hydraulic and pneumatic controls, and emerging technologies.
- **CO4.** Gain knowledge of digital electronics, including number systems, codes, error detection, Boolean functions, circuit design, and code converters.
- **CO5.** Explore signal conditioning techniques using amplifiers, filters, modulation, counters, decoders, and data acquisition principles.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H		L						M			
CO2	H	H		M					M			
CO3	H	M		M					M			
CO4	H	M		M					M			
CO5	H	M	M	M					M			

Syllabus

Introduction: Introduction to Mechatronics, need and applications, elements of mechatronic systems, role of mechatronics in automation, manufacturing, and product development

Sensors and Feedback Devices: Importance of sensors in Mechatronics, Static and Dynamic characteristics of sensors, errors and output impedance of sensors, transducers for measurement of displacement, strain, position, velocity, noise, flow, pressure, temperature, humidity, vibration, liquid level, vision sensors.

Control Elements and Actuators: On/off push buttons, control relays, thermal over load relays, contactors, selector switches, solid state switches. Mechanical actuators – types of motion, gear trains, belt and chain drives, screw rods. Electrical actuators, solenoids, DC drives and AC variable frequency drives, AC and DC motors, BLDC Motor, servomotors, stepper motors, linear motors. Hydraulic and Pneumatic controls, functional diagram - control valves, cylinders and hydro motors, Piezoelectric actuators, Shape memory alloys actuators.

Digital Electronics: Number systems, BCD codes and arithmetic, Gray codes, self-complimenting codes, Error detection and correction principles. Boolean functions using Karnaugh map, Design of combinational circuits, Design of arithmetic circuits. Design of Code converters, Encoders and decoders.

Signal Conditioning: Operational amplifiers, inverting amplifier, differential amplifier, Protection, comparator, filters, Multiplexer, Pulse width Modulation Counters, decoders. Data acquisition – Quantizing theory, Analog to digital conversion, digital to analog conversion.

PLC Programming: Introduction to PLC, simple programs for process control application based on relay ladder logic-Supervisory Control, Data Acquisition Systems (SCADA) and Human Machine Interface (HMI), PLC Principles of operation, PLC sizes, PLC hardware components I/O section, Analog I/O section, Analog I/O modules, digital I/O modules, CPU Processor memory module Programming. Ladder Programming, ladder diagrams, timers, internal relays, counters, data handling, analogue input and output. Application on real time industrial automation systems.

Interfacing Systems: Introduction to interfacing of different hardware in industry, need for networks in industrial plants, hierarchy and structure of networking, RS 232 based network, Ethernet, TCP/IP, MAP/TOP.

Application of Mechatronic Systems: Introduction to factory automation and integration, design of simple Mechatronics systems, Case studies based on the application of mechatronics in manufacturing, autotronics, bionics and avionics pick and place robot, Bar code, Engine Management system, Washing machine etc.

Introduction of Industry 4.0 Concepts & Principles: Introduction of AI, Cyber physical System, Cloud computing, machine learning.

References/Text Material:

1. W. Bolton, "Mechatronics," Pearson Education Asia, 2004.
2. D. G. Alciatore and M. B. Histand, "Introduction to Mechatronics and Measurement Systems," McGraw Hill, 2007.
3. K. K. Kuttan, "Introduction to Mechatronics," Oxford University Press, 2007.
4. D. Shetty and R. Kolk, "Mechatronics System Design," 3rd Ed., PWS Publishing, 2009.
5. C. W. de Silva, "Mechatronics: A Foundation Course," CRC Press, 2010.
6. S. Cetinkunt, "Mechatronics," John Wiley, 2007.
7. J. Stenersons, "Fundamentals of Programmable Logic Controllers Sensors and Communications," Prentice Hall, 2004.
8. HMT, "Mechatronics," Tata McGraw Hill Publishers, 1998.
9. S. Soloman, "Computer Control of Manufacturing Systems," McGraw Hill, 1983.
10. D. Necsulescu, "Mechatronics," Parson Education Asia, 2002.
11. P. Singh, "Microprocessors and Microcontrollers," 1st Ed., Galgotia Pub, 1997.
12. D. Petruzella, "Programmable Logic Controllers," 3rd Ed., Tata McGraw-Hill, 2010.
13. K. Kant, "Computer Based Industrial Control," 2nd Ed., PHI, 1999.

Course Code	Course Name	L	T	P	Credits
ME518	**Micro-Nano Manufacturing Processes**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
This course aims to discuss the creation and manipulation of nanomaterials, exploring bottom-up and top-down approaches, and master the powerful techniques used to shape and characterize these materials. From microfabrication to advanced finishing processes, the student will gain the exposure to create intricate structures with atomic precision.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the significance of micro and nano manufacturing in various industries.
- **CO2.** Learn different methods and techniques for creating nanostructures.
- **CO3.** Gain proficiency in microfabrication and nanofabrication techniques.
- **CO4.** Develop skills for structural characterization of micro and nano structures.
- **CO5.** Explore the applications of MEMS devices in sensing and actuation systems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	L							M			
CO2	H	L	M	M					M			
CO3	H	M	M	H					M			
CO4	H	M	M	H					M			
CO5	H	H	M	M	L				M			

Syllabus

Introduction: Importance of Nano-technology, Emergence of Nanotechnology, Bottom-up and Top-down approaches, challenges in Nanotechnology, Scaling Laws/Sizing effects.

Nano-materials Synthesis and Processing: Methods for creating Nanostructures; Processes for producing ultrafine powders- Mechanical grinding; Wet Chemical Synthesis of nano-materials-sol-gel process, Liquid solid reactions; Gas Phase synthesis of nanomaterials-Furnace, Flame assisted ultrasonic spray pyrolysis; Gas Condensation Processing (GPC), Chemical Vapour Condensation (CVC)- Cold Plasma Methods, Laser ablation, Vapour – liquid –solid growth, particle precipitation aided CVD, summary of Gas Condensation Processing (GPC).

Micro fabrication Techniques: Lithography, Thin Film Deposition and Doping, Etching and Substrate Removal, Substrate Bonding, MEMS Fabrication Techniques, Bulk Micromachining, Surface Micromachining, High- Aspect-Ratio Micromachining

Nanofabrication Techniques: E-Beam and Nano-Imprint Fabrication, Epitaxy and Strain Engineering, Scanned Probe Techniques, Self-Assembly and Template Manufacturing. Honing and Lapping nano-finishing processes. Abrasive flow finishing process and variants, Elastic emission machining, Elasto abrasive finishing, Focused ion beam nano finishing for ultra-thin TEM sample preparation

Hybrid Nano finishing Process: Electrochemical grinding, electrochemical magnetic abrasive finishing, Electro discharge diamond grinding, Fine finishing of gears by electrochemical honing process and Ultrasonic assisted abrasive flow machining Structural Characterization: X-ray diffraction, Small angle X-ray Scattering, Optical Microscope and their description, Scanning Electron Microscopy (SEM), Scanning Probe Microscopy (SPM), TEM and EDAX analysis, Scanning Tunnelling Microscopy (STM), Atomic force Microscopy (AFM).

MEMS devices and applications: Pressure sensor, inertial sensor, Optical MEMS and RFMEMS, Micro-actuators for dual-stage servo systems.

References/Text Material:

1. T. R. Hsu, "MEMS and Microsystems: Design and Manufacture," McGraw-Hill, 2008.
2. M. Madou, "Fundamentals of Microfabrication: The Science of Miniaturization," 2nd Ed., CRC Press, 2002.
3. M. J. Jackson, "Microfabrication and Nanomanufacturing," CRC Press, 2005.
4. B. L. Hornyak, H. F. Tibbals, J. Dutta, and J. J. Moore, "Introduction to Nanoscience and Nanotechnology," CRC Press, 2009.
5. R. F. Egerton, "Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM," Springer, 2005.
6. B. D. Cullity, "Elements of X-Ray Diffraction," 3rd Ed., Prentice Hall, 2002.

Course Code	Course Name	L	T	P	Credits
ME519	Non-Destructive Testing	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

This comprehensive course equips the students with the cutting-edge techniques to inspect materials and components without destruction, safeguarding quality and preventing failures. The techniques of visual inspection, surface methods, thermography, eddy current testing, ultrasonics, acoustic emission, and radiography are explored, understanding their strengths and limitations for different applications.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand NDT principles, compare methods, and evaluate materials' physical characteristics for defect detection.
- **CO2.** Explain Liquid Penetrant and Magnetic Particle Testing, interpreting results and demagnetization techniques for materials
- **CO3.** Elucidate principles, instrumentation, and applications of thermography and eddy current testing methods.
- **CO4.** Discuss ultrasonic testing, covering principles, instrumentation, and advanced techniques like phased array and TOFD
- **CO5.** Gain knowledge on radiography principles, film and filmless techniques, and understand X-ray interactions for flaw detection.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	L							M			
CO2	H	M	L						M			
CO3	H	M	L						M			
CO4	H	M	M						M			
CO5	H	L	M						M			

Syllabus

Overview of NDT: NDT Versus Mechanical testing, Overview of the Non-Destructive Testing Methods for the detection of manufacturing defects as well as material characterization. Relative merits and limitations, Various physical characteristics of materials and their applications in NDT. Visual inspection – Unaided and aided.

Surface NDE Methods: Liquid Penetrant Testing - Principles, types and properties of liquid penetrants, developers, advantages and limitations of various methods, Testing Procedure, Interpretation of results. Magnetic Particle Testing Theory of magnetism, inspection materials Magnetisation methods, Interpretation and evaluation of test indications, Principles and methods of demagnetization, Residual magnetism.

Thermography and Eddy Current Testing: Thermography- Principles, Contact and non-contact inspection methods, Techniques for applying liquid crystals, Advantages and limitation - infrared radiation and infrared detectors, Instrumentations and methods, applications. Eddy Current Testing-Generation of eddy currents, Properties of eddy currents, Eddy current sensing elements, Probes, Instrumentation, Types of arrangement, Applications, advantages, Limitations, Interpretation/Evaluation.

Ultrasonic Testing (UT) and Acoustic Emission: Ultrasonic Testing Principle, Transducers, transmission and pulse-echo method, straight beam and angle beam, instrumentation, data representation, A/Scan, B-scan, C-scan. Phased Array Ultrasound, Time of Flight Diffraction. Acoustic Emission Technique – Principle, AE parameters, Applications

Radiography: Principle, interaction of X-Ray with matter, imaging, film and film less techniques, types and use of filters and screens, geometric factors, Inverse square, law, characteristics of films - graininess, density, speed, contrast, characteristic curves, Penetrometers, Exposure charts, Radiographic equivalence. Fluoroscopy- Xero-Radiography, Computed Radiography, Computed Tomography

References/Text Material:

1. Baldev Raj, T.Jayakumar, M.Thavasimuthu “Practical Non-Destructive Testing”, Narosa Publishing House, 2009
2. Ravi Prakash, “Non-Destructive Testing Techniques”, 1st revised Ed., New Age International Publishers, 2010
3. ASM Metals Handbook, “Non-Destructive Evaluation and Quality Control”, American Society of Metals, Metals Park, Ohio, USA, 200, Volume-17
4. Paul E Mix, “Introduction to Non-destructive testing: a training guide”, Wiley, 2nd Ed. New Jersey, 2005
5. Charles, J. Hellier, “Handbook of Nondestructive evaluation”, McGraw Hill, New York 2001.

Course Code	Course Name	L	T	P	Credits
ME520	Non-Traditional Manufacturing Processes	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective
This comprehensive course aims to impart knowledge on unconventional tools and forces, from ultrasonic vibrations and chemical baths to electrical sparks and laser beams. The mechanical, chemical, electrochemical, and thermal AMPs are explored, understanding their principles, capabilities, and limitations.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the classification and evolution of AMPs, emphasizing the need for advanced machining processes.
- **CO2.** Explore Mechanical Type AMPs (USM, RUM, AJM, WJM, AWJM) - process principles, parameters, capabilities, applications, limitations.
- **CO3.** Study Advanced Fine Finishing Processes (AFM, MAF, MRAF) - process principles, equipment, parameters, capabilities, applications, limitations.
- **CO4.** Examine Chemical Type AMPs (CHM, PCM, BCM) - process principles, details.
- **CO5.** Gain knowledge of Thermal Type AMPs (EDM, WEDM, LBM, EBM, IBM, PAM) - process principles, parameters, surface finish, capabilities, applications, limitations.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	M	H	M					M			
CO3	H	M	M	M					M			
CO4	H	M	L	H					M			
CO5	H	M	H	L					M			

Syllabus

Introduction: Types of advanced manufacturing processes; Evolution, need, and classification of advanced machining processes (AMPs).

Mechanical Type AMPs: USM, Rotary Ultra Sonic Machining (RUM), Abrasive Jet machining (AJM), Water Jet machining (WJM), Abrasive Water Jet machining (AWJM) processes - Process principle and mechanism of material removal; Process Parameters; Process Capabilities; Applications; Operational characteristics; Limitations.

Advanced Fine Finishing Process: Abrasive Flow Machining (AFM), Magnetic Abrasive Finishing (MAF), Magneto Rheological Abrasive Finishing (MRAF) - Process principle; Process equipment; Process Parameters; Process Capabilities; Applications; Limitations.

Chemical Type AMPs: Process principle and details of Chemical Machining (CHM), Photo-Chemical Machining (PCM), and Bio-Chemical Machining (BCM) processes.

Electro Chemical Type AMPs: ECM - Process principle; Mechanism of material removal; Process Parameters; Process Capabilities, Tooling design; Choice and analysis of process parameters; Kinematics and dynamics of ECM; Surface finish, accuracy, Applications,

Thermal Type AMPs: EDM, Wire Electro Discharge Machining (WEDM), LBM, EBM, IBM, PAM processes – Process principle and mechanism of material removal; Process parameters and characteristics; Surface finish and accuracy, Process Capabilities; Applications; Limitations.

Derived and Hybrid AMPs: Electro Stream Drilling (ESD), Shaped Tube Electro Machining (STEM), Electro Chemical Honing (ECH), Electro Chemical Deburring (ECDE), Electro Chemical Discharge Machining (ECDM) - Process Parameters; Process Capabilities; Applications; Limitations, Introduction to form machining.

References/Text Material:

1. P. C. Pandey and H. S. Shan, "Modern Machining Processes," Tata McGraw-Hill Publishing Co. Ltd., 1977.
2. A. Ghosh and A. K. Mallik, "Manufacturing Science," Affiliated East-West Press Ltd., 1985.
3. G. F. Benedict, "Nontraditional Manufacturing Processes," Marcel Dekker, Inc., 1987.
4. J. A. McGeough, "Advanced Methods of Machining," Chapman and Hall, 1988.
5. P. K. Mishra, "Nonconventional Machining," Narosa Publishing House, 1997.
6. V. K. Jain, "Advanced Machining Processes," Allied Publishers, 2002.
7. V. K. Jain, "Advanced Machining Processes," Allied Publishers, 1980.
8. J. P. Davim, "Modern Machining Technology," Elsevier, 2011.

Course Code	Course Name	L	T	P	Credits
ME521	Production and Operation Management	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The main objective of this course is to provide details on concept of production, facility location and design, production scheduling, mass production techniques. Also, it aims to give information on quality, maintenance and modern production management

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand various operations strategies, forecasting methods and facility location
- **CO2.** Realize in detail inventory control and aggregate planning
- **CO3.** Understand several Modern Production management tools and maintenance followed in industries

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	M	H	H	M	M	H	M	L	L	M		M
CO2		M	M	M	H	M	M	L	M	H	L	H
CO3	H		M	L	H	M	M	L		M	M	M

Syllabus

Introduction: Introduction to Production and Operations Management, Operations Strategy in a global economy; Operations Management and Productivity, Types and Characteristics of Manufacturing and Service Systems, Product Design

Forecasting: Introduction to Forecasting, Demand pattern, Forecast Models-Quantitative methods of forecasts, Qualitative Methods of Forecasting, Forecasting Error, Case studies

Facility Location: Facility Capacity, Facility Location, Facility Layout, Line Balancing, Cellular Layout, Service Facility Layout

Inventory control: Introduction to Inventory Management, Various costs involved in inventory, management, EOQ Models of Inventory Management, Various variations of EOQ, Inventory Models with Uncertain Demand -I, II, Miscellaneous Systems and Issues, Inventory Control and Supply Chain Management

Aggregate Planning: Aggregate Sales and Operations Planning, Aggregate planning Techniques, Material requirement Planning, Improvements in the MRP system, Lot Sizing in MRP Systems, Various Scheduling techniques

Maintenance: Maintenance Management, Total Productive Maintenance

Modern Production management: Total Quality management, Just –In Time (JIT), Lean Manufacturing, Kanban Production System, Case Discussions

References/Text Material:

1. S. Eilon, "Elements of Production Planning and Control," McMillon Company, 1962.
2. E. S. Buffa, "Modern Production/Operations Management," John Wiley, 1983.
3. R. Pannerselvam, "Production and Operations Management," PHI Learning, 2006.
4. K. Aswathappa and K. Sridhar Bhat, "Production and Operations Management," Himalaya Publishing, 2018.
5. W. J. Stevenson, "Operations Management," McGraw-Hill Education, 2018.

Course Code	Course Name	L	T	P	Credits
ME522	Tool Design	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective
This comprehensive course equips the students with the expertise to design effective tools and secure work-holding devices, ensuring precision and efficiency in machining operations. The principles of jigs and fixtures are explored, understanding how to properly locate and clamp workpieces for various tasks.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the importance of tool design, jigs, and fixtures in manufacturing.
- **CO2.** Learn about work holding devices, including how they locate and clamp materials.
- **CO3.** Gain knowledge in designing drill jigs, including selecting the right drill bush and understanding different types of drill jigs.
- **CO4.** Develop skills for the design of fixtures for milling and turning operations, focusing on how they are built and what they do.
- **CO5.** Explore the basics of press tool design, including cutting operations, types of presses, and designing different types of dies.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	M							M			
CO3	H	M							M			
CO4	H	M	H	H					M			
CO5	H	M		M					M			

Syllabus

Introduction: Tool design – An overview, Introduction to Jigs and fixtures.

Work holding devices: Basic principle of six-point location, Locating methods and devices, Principle of clamping and Types of clamps.

Design of jigs: Type of Drill bushes, Classification of drill jigs, Design of drill jigs.

Design of fixtures: Design of milling fixtures, Design of turning fixtures.

Introduction of press tool design: Introduction to Die cutting operations, Introduction to press and classifications, Die set assembly with components, Introduction to Centre of pressure, Examples of center of pressure, Design of piercing die, Design of blanking die, Progressive, Compound and Combination dies.

Design of cutting tools: Introduction to cutting tools, Design of single point tool, Design of drill bit, Design of milling cutter.

Brief introduction of NC machines work holding devices: Tool design for NC machines- An introduction, Fixture design for NC Machine, cutting tools for NC Machine, Tool holding methods for NC Machine, ATC and APC for NC Machine, Tool presetting for NC Machine.

References/Text Material:

1. F. W. Wilson, "Fundamentals of Tool Design," ASME, PHI, 2010.
2. C. Donaldson, G. H. Lecain, and V. C. Goold, "Tool Design," TMH, 2010.
3. P. Joshi, "Jigs and Fixtures Design Manual," 2nd Ed., McGraw-Hill, 2002.
4. K. Venkataraman, "Design of Jigs, Fixtures and Press Tools," 1st Ed., Wiley Athena Academic, 2015.

Course Code	Course Name	L	T	P	Credits
ME523	**Aerodynamics**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The main objective of studying this course is to introduce the concept of inviscid, incompressible and compressible flows. It also aims to learn various concepts of fluid mechanics for application in aerodynamics, and develop the ability and skill to design an aerodynamics system.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the principles of flight and vehicle aerodynamics.
- **CO2.** Analyze and evaluate systems associated with potential flow.
- **CO3.** Analyze and apply the concepts of fluid mechanics for flow over airfoil.
- **CO4.** Analyze and apply the concepts of fluid mechanics for flow past finite wings.
- **CO5.** Estimate the lift and drag over a vehicle body using the principles of aerodynamics.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	H	M	M					M			
CO3	H	H	M	M					M			
CO4	H	H	M	M					M			
CO5	H	M	M	M					M			

Syllabus

Introduction to Aerodynamics and Concepts: Introduction: Importance of Aerodynamics in flights and automobiles, Aerofoils, wings and their nomenclature, Characteristics of Airfoil, Aerodynamic Forces and Moments (Lift, drag and pitching moment coefficients), A brief review on Continuity, Momentum and Energy Equations, Application of Momentum Equation for the Estimation of Drag of a Two dimensional Body, Substantial Derivatives, Pathlines and Streamlines of a Flow, Angular Velocity, Vorticity and Strain; Circulation; Stream Function; Velocity Potential.

Inviscid Incompressible Flows: Elementary Flows and their Superposition (Uniform flow, Source Flow, Source- Sink Flows, Doublet Flow, Non- lifting Flow over a Circular Cylinder, Vortex Flow, Lifting Flow over a Cylinder), Kutta – Joukowski Theorem and the Generation of Lift, Non-lifting flows over arbitrary bodies: Numerical Source Panel method.

Incompressible flows over airfoils: Kutta Condition, Kelvin’s Circulation Theorem, Starting Vortex, Classical Thin Airfoil Theory of Symmetric and Cambered Airfoils, Lift and Moment Coefficients, Center of Pressure, Predicting Zero Lift Angle of Attack, Flapped Airfoils, Effects of Thickness.

Finite Wing Theory: The Concept of Downwash and Induced Drag – Classical Theorems: Curved Vortex Filament, Biot-Savart Law, Helmholtz's Vortex Theorems – Method of Analysis: Prandtl's Classical Lifting Line Theory, Modern Numerical Lifting Line Method, Lifting Surface Theory, Modern Vortex Lattice Numerical Method.

Compressible flow past airfoils: Linearized Velocity potential, Prandtl Glauert compressibility corrections, Critical Mach number, drag divergence Mach number, supercritical airfoils, Linearized supersonic flow, Method of characteristics, Supersonic flow over airfoils and wings, subsonic/supersonic leading edge, Hypersonic flows, real gas effects, Newtonian theory, lift and drag in hypersonic flows.

Automotive Aerodynamics: Automobiles as bluff bodies, flow field around the vehicle, drag force, types of drag force, analysis of aerodynamic drag, drag coefficient of vehicles, strategies for aerodynamic development, low drag profiles, fuel consumption and performance potential of vehicle aerodynamics, effects of platooning, Case studies on modern vehicles

References/Text Material:

1. J.D. Anderson, "Fundamentals of Aerodynamics," 6th Ed., McGraw Hill, 2016.
2. A.M. Kuethe and C. Chow, "Foundations of Aerodynamics; Bases of Aerodynamic Design," 5th Ed., Wiley, 1998.
3. L. J. Clancy, "Aerodynamics," John Wiley & Sons, 1975.
4. J. Katz and A. Plotkin, "Low Speed Aerodynamics," McGraw Hill, New York, 1991.
5. S. H. Collicott, D. Valentine, E. L. Houghton, P. W. Carpenter, "Aerodynamics for Engineering Students," 6th Ed., Butterworth-Heinemann (Elsevier), 2013.
6. J. J. Bertin and R. M. Cummings, "Aerodynamics for Engineers," 5th Ed., Pearson, 2008.

Course Code	Course Name	L	T	P	Credits
ME524	Automobile Engineering	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
The objective of the course is to understand the automotive fundamentals: chassis, engine, performance, emissions, fuel/ignition systems, and safety. The students will gain knowledge on steering, suspension, braking, transmission, electricals, comfort, and restraint systems.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Explain the different vehicle systems and subsystems applying fundamental automotive engineering principles.
- **CO2.** Evaluate SI and CI engine performance, identifying factors influencing fuel efficiency and emissions
- **CO3.** Design innovative solutions for improved automotive systems, integrating advanced technologies
- **CO4.** Assess environmental impact and safety of hybrid and electric vehicles, considering advantages and challenges.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								H			
CO2	H	H	M	M					H			
CO3	H		H	M					H			
CO4	H	M		M			H		H			

Syllabus

Introduction: Chassis, layout, frame and body construction.

Engine: classification, working, and advancements in IC engines

Engine Performance and Emissions: Performance and emission characteristics of SI and CI engines, Emission control system

Fuel and Lubrication: Fuel and Ignition system, Lubricating and cooling system.

Steering, Suspension, and Braking System, Transmission system and Electricals.

Automotive comfort and safety

Hybrid and electric vehicles

References/Text Material:

1. W.H. Crouse and D.L. Anglin, "Automotive Mechanics," 10th ed., Tata McGraw Hill, 2007.
2. K. Singh, "Automobile Engineering," vol. 1 and 2, 7th ed., Standard Publishers, 1997.
3. J. Heitner, "Automotive Mechanics: Principles and Practices," East-West Press, 1999.

Course Code	Course Name	L	T	P	Credits
ME525	Power Plant Engineering	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective
The objective of the course is to impart knowledge on the conventional and non-conventional energy conversion systems and also expose the students to the impact of greenhousegas emissions on the environment.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the current utilization and future potential of conventional and renewable energy sources.
- **CO2.** Analyze the energy conversion processes in hydel, steam, gas turbine, diesel, nuclear, and also from renewable sources like solar, wind, ocean, geothermal, and biomass power plants.
- **CO3.** Explore the impact of energy conversion on greenhouse gas emissions and the economics of power plants.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H						M		M			
CO2	H	H	M	M			M		M			
CO3	H	M	M	M			H		M			

Syllabus

Energy Scenario: Present utilization of conventional and renewable sources of energy, Potential and realization of renewable sources, future trends of energy conversion and utilization, Impact on greenhouse gas emissions, Current practices to control emissions from power plants

Conventional energy conversion: Hydel, Steam (Rankine and organic Rankine cycle), Gas turbine (combined cycle & cogeneration), Diesel and Nuclear Power Plant

- Layout, function of different components and types, Power Plant Economics

Renewable energy conversion: Solar thermal energy, Wind, Ocean, Geothermal, Biomass

- Energy Conversion Principles, types and working

References/Text Material:

1. P.K. Nag, "Power Plant Engineering," Tata McGrawHill, 2017.
2. Arora and Domkundwar, "Power Plant Engineering," Dhanpat Rai & Co., 2016.
3. G.R. Nagpal and S.C. Sharma, "Power Plant Engineering," Khanna Publishers, 1995.

Course Code	Course Name	L	T	P	Credits
ME526	Solar Energy Utilization	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
The aim of the course is to impart knowledge on solar radiation fundamentals and apply the heat transfer principles to systems involving energy conversion from solar energy including, collectors and storage systems.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Understand the fundamentals of solar radiation, its applications and uses in solar thermal systems.
CO2. Apply heat transfer principles to solar flat plate collectors, concentrating collectors and analyze its thermal performance.
CO3. Discuss the different energy storage systems
CO4. Assess the utilization of solar thermal energy for energy conversion

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H						M		M			
CO2	H	M	M	H			H		M			
CO3	H	L		L			H		M			
CO4	H	H	H	M			H		M			

Syllabus

Solar Radiation Fundamentals: Measurement and Estimation of solar radiation, Applications of Solar thermal energy

Flat Plate Collector: Parts, working, heat transfer analysis, calculation of useful heat gain. Advancements in flat plate collector.
Evacuated collectors – parts, working, and heat transfer analysis.

Concentrating Collectors: Parabolic collector, Parabolic trough, Fresnel lens; Solar air heaters – parts, working, and heat transfer analysis

Solar Energy Conversion: Solar thermal energy storage systems, Utilization of solar thermal energy for energy conversion

References/Text Material:

1. J.A. Duffie and W.A. Beckman, "Solar Engineering of Thermal Processes," John Wiley & Sons, 2013.
2. D.Y. Goswami, "Principles of Solar Engineering," CRC Press, 3rd ed., 2015.
3. S.P. Sukhatme and J.K. Nayaka, "Solar Energy," McGraw Hill, 4th ed., 2017.

Course Code	Course Name	L	T	P	Credits
ME527	**Waste to Energy Conversion Systems**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
The aim of the course is to introduce the different sources of wastes and its potential for energy conversion. The course also intends to discuss the different pathways of energy conversion like biochemical, thermochemical, hydrothermal routes etc.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand different waste sources, waste characterization, and the potential of waste-to-energy on both Indian and global scales.
- **CO2.** Comprehend the thermochemical, biochemical, and hydrothermal processes involved in waste-to-energy conversion, leading to the production of various fuel products.
- **CO3.** Assess the utilization of waste for power production
- **CO4.** Discuss the impact of conventional and waste-derived-energy on the environment

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H						H		M			
CO2	H	M	M	M			M		M			
CO3	H	M		M			H		M			
CO4	H	L		M			H		M			

Syllabus

Waste Sources: Municipal Solid waste, plant waste, agricultural waste, and other biomass wastes. Waste to Energy Potential – Indian and Global Scenario. Waste characterization

Waste to energy via thermochemical processes: combustion, incineration, gasification, pyrolysis – Production of refused derived fuel (RDF), biochar, producer gas, syngas, briquettes

Waste to energy via biochemical processes: anaerobic digestion, algae culture and oil extraction, fermentation, transesterification. – Production of biogas, biodiesel, bio-oil, bio ethanol.

Waste to energy via hydrothermal processes: hydrothermal liquefaction and hydrothermal carbonization. – Production of biocrude oil and hydrochar

Comparison of conventional fuels with waste-derived fuels: Utilization and power generation of waste derived fuels, general method for the estimation and calculation of carbon footprint.
References/Text Material:

1. M.J. Rogoff and F. Screve, "Waste-To-Energy: Technologies and Project Implementation," Elsevier, 2019.
2. G.C. Young, "Municipal Solid Waste to Energy Conversion Processes: Economic, Technical, and Renewable Comparisons," Wiley, 2010.
3. D.L. Klass, "Municipal Solid Waste to Energy Conversion Processes: Economic, Technical, and Renewable Comparisons," Elsevier, 1998.
4. M.M. El-Halwagi, "Biogas Technology, Transfer and Diffusion," Springer Dordrecht, 2014.

Course Code	Course Name	L	T	P	Credits
ME528	**Experimental Methods in Fluid Flow and Heat Transfer**	**3**	**0**	**0**	**3**

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The aim of the course is to introduce the working of various thermal, fluid, and transport property measurements. The course also aims to analyze the experimental methods and carry out uncertainty analysis of experiments.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Understand the importance of experiments, measuring systems, and the analysis of uncertainties in experimental measurements.

CO2. Study pressure, flow, temperature, and thermal-radiation measurements, including various measurement techniques and instruments.

CO3. Explore transport-property measurements, including thermal conductivity, viscosity, heat transfer, humidity, and pH measurements.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H		H					M			
CO2	H	H	M	H					M			
CO3	H	H	M	H					M			

Syllabus

Introduction to experimental methods: Why conduct experiments? Measuring systems. Basic concepts of static and dynamic measurements. Uncertainty in measurements. Systematic and random errors. Error analysis and uncertainty propagation.

Pressure measurements: Mechanical and Electrical pressure transducers. In-flow and Wall pressure measurements.

Flow measurement: Flow-obstruction methods. Flow measurement by drag effects. Hot-wire and hot-film anemometers. Positive-displacement methods. Flow visualisation: Marker and Optical techniques. Optical flow measurements: Laser Doppler anemometer, Planar laser-induced fluorescence (PLIF), particle image velocimetry (PIV), interferometric method.

Temperature measurements: Thermodynamic viewpoints. Liquid in glass thermometer, temperature measurement by electrical effects, temperature measurement by radiation, transient temperature measurement, thermocouple compensation, temperature measurements in moving fluids.

Thermal-radiation measurements: emissivity measurement, reflectivity and transmissivity measurement.

Transport-property measurements: Thermal conductivity measurements, measurement of viscosity, gas diffusion, convective heat transfer measurement, humidity measurement, heat flux meters, pH measurement.

References/Text Material:

1. J.P. Holman, "Experimental Methods for Engineers," 6th ed., McGrawHill, 1994.
2. E.O. Doeblin, "Engineering Experimentation," McGrawHill, 1995.
3. R.J. Goldstein, "Fluid Mechanics Measurements," Hemisphere Publishing.
4. R.P. Benedict, "Fundamentals of Temperature, Pressure and Flow Measurement," John Wiley & Sons.
5. Holman, J.P., Experimental Methods for Engineers, McGrawHill, 6^{th} ed., 1994
6. Doeblin E.O., Engineering Experimentation, McGrawHill, 1995.
7. Goldstein R.J., Fluid Mechanics Measurements, Hemisphere Publishing,
8. Benedict R.P., Fundamentals of Temperature, Pressure and Flow Measurement, John Wiley & Sons.,

Course Code	Course Name	L	T	P	Credits
ME529	Advanced Thermodynamics	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective
The aim of the course is to impart the knowledge of entropy, Maxwell, and Clausius-Clapeyron equations. The course also aims to discuss gas mixtures and carry out chemical kinetic analysis.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Review the First & Second laws, entropy, and entropy generation in thermodynamics.
- **CO2.** Learn thermodynamic property relations, including Maxwell relations and Clausius-Clapeyron equation.
- **CO3.** Gain knowledge of gas mixtures, including multi-component and multi-phase systems, equations of state, ideal and real gas mixtures, and entropy changes in mixing.
- **CO4.** Study irreversible thermodynamics and principles of entropy generation minimization.
- **CO5.** Conduct chemical kinetic analysis and discuss the different types of flames and its properties

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	M	L	M					M			
CO3	H	M	L	M					M			
CO4	H	M	L	M					M			
CO5	H	H	M	M					M			

Syllabus

Review of basic thermodynamics: First & Second laws, Concept of entropy and entropy generation, Entropy balance for closed & open systems; Concept of exergy & irreversibility, Exergy analyses of open and closed system

Thermodynamic property relations: Maxwell relations; Relations involving enthalpy, internal energy and entropy; Mayer relation, Clausius-Clapeyron equation, Joule-Thompson experiment.

Properties of gas mixtures: Multi-component and multi-phase systems, Equations of states and properties of ideal and real gas mixtures, Change in entropy in mixing.

Irreversible thermodynamics: Finite time thermodynamic principle, Optimization of various thermodynamic systems, Principles of entropy generation minimization.

Thermodynamics of reactive systems: Combustion and thermochemistry, Reactant and product mixtures, Adiabatic flame temperature, Chemical equilibrium, Equilibrium products of combustion.

Chemical Kinetics: Global versus elementary reactions, Elementary reaction rates, Rates of reaction for multistep mechanisms.

Flames: Types of flames, Simplified analyses of premixed & diffusion flames, Factors influencing flame velocity and thickness, Quenching, flammability and ignition, Flame stabilization.

References/Text Material:

1. A. Bejan, "Advanced Engineering Thermodynamics," 4th ed., John Wiley & Sons, 2016.
2. S.R. Turns, "An Introduction to Combustion: Concepts and Applications," 3rd ed., McGraw Hill, 2012.
3. D.E. Winterborne, "Advanced Thermodynamics for Engineers," 2nd ed., Butterworth-Heinemann, 2015.
4. J.M. Smith, H.C. Ness, M.M. Abbott, "Introduction to Chemical Engineering Thermodynamics," 7th ed., McGraw Hill Education, 2009.
5. M.D. Koretsky, "Engineering and Chemical Thermodynamics," Wiley, 2009.

Course Code	Course Name	L	T	P	Credits
ME530	Gas Dynamics and Jet Propulsion	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
The aim of the course is to impart knowledge on kinetics of gases and its effects on physical systems. The course also intends to explore the phenomenon of shocks and jet propulsion.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the governing equations and properties of inviscid-compressible flows, including static and stagnation properties, continuity, momentum, and energy equations.
- **CO2.** Learn about isentropic flows through variable area passages, including the behavior of nozzles, diffusers, and critical pressure ratios.
- **CO3.** Explore the phenomena of shocks in fluid flow, including normal and oblique shocks, their causes, effects, and the relevant equations.
- **CO4.** Gain knowledge of jet propulsion fundamentals, thermodynamic cycle analysis, and the performance of different propulsive devices.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	M		M					M			
CO3	H	M		M					M			
CO4	H	M		M					M			

Syllabus

Introduction: Governing equations for inviscid-compressible flows - static and stagnation properties - speed of sound and Mach number, continuity, momentum and energy equations, mathematical derivations of Bernoulli's equation for incompressible and compressible fluid flows, effects of compressibility on the fluid flow measurements, application incompressible fluid flow standard tables.

Isentropic flows: through variable area passage ducts - Flow through nozzles and diffusers, chocked flow, critical pressure ratio, application of equation of critical pressure ratio, variable cross-sectional area flow.

Flow with shocks: Normal and oblique shocks, causes and effects of shocks, Prandtl-Meyer and Rankin-Hugoniot equation equations. Flow with effects of friction and heat transfer: Fanno flow, isothermal fluid flow, Rayleigh flow, concepts of maximum length and its variation on subsonic and supersonic fluid entry.

Jet Propulsion: Fundamentals of jet propulsion - Thermodynamic cycle analysis and efficiencies of propulsive devices. Thrust equation, classification and comparison of ram jets, turbojets, pulse jets and rockets. Performance of turbo-prop, turbo-jet and turbo-fan engines. Augmentation of thrust.

References/Text Material:

1. S.M. Yahya, "Fundamentals of Compressible Flow," 6th Ed., New Age International Publishers, 2010.
2. J.E. John and T.G. Keith, "Gas Dynamics," 3rd Ed., Pearson, 2005.
3. J.D. Anderson Jr., "Modern Compressible Flow: With Historical Perspective," 3rd Ed., McGraw-Hill Education, 2013.
4. G.C. Oates, "Aerothermodynamics of Gas Turbine and Rocket Propulsion," 3rd Ed., AIAA Education Series, 2017.

Course Code	Course Name	L	T	P	Credits
ME531	Internal Combustion Engines	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to impart knowledge on the parts and working of internal combustion engines. The course also intends to analyze the different engines for their performance and emissions.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Understand IC engines: classification, applications, and thermodynamic cycles.

CO2. Study combustion in SI and CI engines: efficiency, flame propagation, and ignition.

CO3. Explore advanced fuel injection systems, superchargers, and turbochargers for engine performance.

CO4. Analyze engine performance, emissions, testing, and alternative fuels for sustainable and efficient operation.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	L							M			
CO2	H	H		M					M			
CO3	H	M		M					M			
CO4	H	H	M	M			H		M			

Syllabus

Introduction to IC engines: Classification, Applications, thermodynamics cycles. Combustion in SI engines, CI engines. Adiabatic flame temperature and enthalpy of products.

Combustion, fuel injection and boosting: Advanced fuel injection systems (HCCI, RCCI, CRDI, MPFI, GDI, CDI engines), Superchargers and Turbochargers.

Performance and emissions: SI, CI engines, Engine Testing and Measurement, Alternative fuels for IC engines.

References/Text Material:

1. J.B. Heywood, "Internal Combustion Engine Fundamentals," McGraw-Hill Education, 2017.
2. C.R. Ferguson and A.T. Kirkpatrick, "Internal Combustion Engines: Applied Thermosciences," 3rd ed., Wiley, 2015.
3. R. Stone, "Introduction to Internal Combustion Engines," 4th ed., Palgrave Macmillan, 2012.
4. V. Ganesan, "Internal Combustion Engines," 4th ed., Tata McGraw-Hill Education, 2012.

Course Code	Course Name	L	T	P	Credits
ME532	Introduction to Turbulent Flows	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The aim of the course is to impart knowledge on the nature and behavior of turbulent flows, from statistical tools to diverse flow types.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the fundamental characteristics of turbulence, including its origin, irregularity, and three-dimensional motions.
- **CO2.** Learn the statistical description of turbulence, including probability density, moments, and energy cascade.
- **CO3.** Explore turbulent transport phenomena, including Reynolds decomposition, turbulent stresses, and the mixing-length model.
- **CO4.** Gain knowledge of different types of turbulent flows, including free shear flows and wall-bounded flows, and their characteristics.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	M		M					M			
CO3	H	M	M	M					M			
CO4	H	M		M					M			

Syllabus

Introduction: Origin of turbulence, irregularity, diffusivity, three-dimensional motions, dissipation, wide spectrum, length scales;

Statistical Description of Turbulence: Probability density, moments, correlations, integral micro scales, homogeneous and isotropic turbulence, Kolmogorov hypothesis, energy cascade, turbulence spectra;

Turbulent Transport: Reynolds decomposition, turbulent stresses, Reynolds equations, mixing-length model, and dynamics of turbulence;

Free Shear Flows: Mixing layer, turbulent wakes and jets, grid turbulence;

Wall-bounded Turbulent Flows: Channel and pipe flows, Reynolds stresses, turbulent boundary layer equations, logarithmic-law of wall;

Introduction to turbulence modeling: Reynolds averaged Navier-Stokes equations, RANS modelling, DNS and LES and experimental methods.

References/Text Material:

1. S.B. Pope, "Turbulent Flows," Cambridge University Press, 2000.
2. J. Mathieu and J.-P. Chollet, "An Introduction to Turbulent Flow," Springer, 2005.
3. P.A. Davidson, "Turbulence: An Introduction for Scientists and Engineers," Oxford University Press, 2015.

Course Code	Course Name	L	T	P	Credits
ME533	**Heating Ventilation and Air Conditioning**	**3**	**0**	**0**	**3**

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The course intends to apply refrigeration and air conditioning principles to facilitate the design and implementation of effective air conditioning and ventilation systems, mastering from principles to components and distribution.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Apply principles refrigeration and air conditioning processes to real systems.
- **CO2.** Estimate the cooling load/heating load with respect to a location for air conditioning.
- **CO3.** Identify the processes required for air conditioning, and design of various components and systems.
- **CO4.** Design the air distribution system for air conditioning and ventilating

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H	M	H			M		M			
CO2	H	H	H	H			M		M			
CO3	H	M		M			M		M			
CO4	H	H	H	H			M		M			

Syllabus

Principles of refrigeration: Carnot refrigeration cycle, unit of refrigeration, capacity, coefficient of performance. Refrigeration systems, vapour compression system, theoretical and practical cycles, system components, compressors, condensers, expansion devices, evaporators, refrigerants. Air refrigeration cycle, Vapour absorption refrigeration system.

Psychrometry: Psychrometric processes, determination of condition of air entering conditioned space. Air conditioning systems, summer, winter and year-round-year air conditioning systems, central and unitary systems. Requirement of air conditioning, human comfort, comfort chart and limitations, effective temperature, factors governing effective temperature, design considerations. Cooling load calculations, various heat sources contributing heat load, solar load, equipment load, infiltration air load, duct heat gain, fan load, moisture gain through permeable walls and fresh air load, Design of air conditioning systems.

Duct design: Equal friction method, static regain method, velocity reduction method, Air distribution systems, Analysis for heating and cooling systems, Insulation.

Heating systems: Warm air systems, hot water system, steam heating systems, panel and central heating systems, Heat pump circuit, and Heat sources for heat pump.

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.

Air Conditioning System: Air conditioning equipments and control systems, air filters, humidifiers, fan, blowers, control systems for temperature and humidity – noise control. Installation and charging of refrigeration unit, Testing for leakage, Cause for faults and rectification.

References/Text Material:

1. N.C. Harris, "Modern Air Conditioning Practice," 2nd Ed., McGraw-Hill, 1974.
2. W.F. Stoecker, "Refrigeration & Air Conditioning," 2nd Ed., McGraw Hill, New York, 1987.
3. R.J. Dossat, "Refrigeration & Air Conditioning," 4th Ed., Prentice Hall, 1997.
4. C.P. Arora, "Refrigeration & Air Conditioning," 2nd Ed., McGraw Hill, 2000.
5. W.F. Stoecker, "Principles of Air Conditioning," 2nd Ed., Industrial Press, 1977.
6. J.M. Laub, "Heating & Air Conditioning of Buildings," Holt, Rinehart and Winston, 1963.
7. J.R. Kell and P.L. Martin, "Air Conditioning & Heating of Buildings," 6th Ed., Architectural Press, 2007.
8. J.L. Levenhagen and D.H. Spethmann, "Heating Ventilating and Air Conditioning Controls and Systems," McGraw-Hill, 1993.
9. "Carrier's Handbook for Design of Unit Air Conditioners," 14th Ed., Kenrick Place Media Ltd, 1996.

Course Code	Course Name	L	T	P	Credits
ME534	**Refrigeration and Air-Conditioning**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to impart knowledge on the refrigeration and air conditioning technology, from diverse systems and psychrometrics to optimizing performance and evaluating load demands.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the principles and applications of various natural and artificial refrigeration systems.
- **CO2.** Identify methods for performance improvement of vapor compression refrigeration systems.
- **CO3.** Demonstrate the working principles of air, vapor absorption, steam-jet, vortex tube, thermoelectric and magnetic refrigeration systems.
- **CO4.** Analyze air-conditioning processes using the principles of Psychrometry.
- **CO5.** Evaluate cooling and heating loads in an air-conditioning system.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	L	M	M			H		M			
CO3	H	M	H	M					M			
CO4	H	H	M	M			H		M			
CO5	H	H	M	M			H		M			

Syllabus

Introduction: Basic Definitions of Refrigeration and Air-Conditioning, History of Refrigeration, Natural and Artificial Refrigeration Methods, Techniques to produce low temperatures, A Brief Review on Thermodynamics, Heat Transfer and Fluid Mechanics, Applications of Refrigeration. Components of Refrigeration Systems: Compressors: Positive Displacement (Reciprocating and Rotary), Dynamic (Centrifugal and Axial) Compressors, Condensers and Evaporators (Both Natural and Forced Convection type), Expansion Devices and other components of the system.

Air Refrigeration: Air Refrigeration Cycles - reversed Carnot cycle, Bell-Coleman cycle analysis, various methods of Aircraft Refrigeration (Simple, Bootstrap, Reduced ambient and Regenerative air cooling) systems: Analysis, Merits and demerits.

Vapor Compression Refrigeration System (VCRS): Ideal VCR cycle (Working, Analysis and Limitations), Standard VCRS (Working and Analysis), Methods to improve performance of VCRS (Sub cooling, superheating and Capillary Liquid-Suction Heat Exchanger), Multi-

Stage VCRS (Flash Gas removal, Flash Inter cooling and Water inter cooling), Cascade Refrigeration.

Refrigerants: Classification, Nomenclature of refrigerants, Desirable Properties of an ideal refrigerant, Selection of Refrigerants and, A brief discussion on Ozone layer Depletion and Global Warming.

Vapor Absorption systems: Vapor Absorption Refrigeration Systems (Working and Analysis), Absorbent - Refrigerant combinations, Water-Ammonia Systems, Water-Lithium Bromide System, Contrast between the two systems, Modified Version of Aqua-Ammonia System with Rectifier and Analyzer Assembly.
Other Refrigeration systems: Brief Discussion on (i) Steam-Jet refrigeration system, (ii) Vortex tube refrigeration, (iii) Thermoelectric refrigeration system and (iv) Magnetic refrigeration.

Psychrometry: Classification of Air-Conditioning Systems, ASHRAE Nomenclature, Applications of Air-Conditioning, Psychrometry - Air-water vapor mixtures, Psychrometric Properties, Psychrometric or Air-Conditioning processes, Psychrometric Chart.

Air-Conditioning Systems: Classification of Air-Conditioning Systems, Psychrometry of Air-Conditioning Systems, Thermal Comfort (Definition and Psychrometric Properties for Thermal Comfort), Mathematical Analysis of Air-Conditioning Systems, Cooling and Heating Load Estimation, a brief discussion on Ventilation.

References/Text Material:

1. C.P. Arora, "Refrigeration and Air Conditioning," 2nd Ed., Tata McGraw-Hill, 2000.
2. Manohar Prasad, "Refrigeration and Air Conditioning," 3rd Ed., New Age International, 2004.
3. R.D. Dossat, "Principles of Refrigeration," 4th Ed., Pearson Education India, 2002.
4. P.L. Ballaney, "Refrigeration and Air Conditioning," Standard Ed., Khanna Publishers, 1972.

Course Code	Course Name	L	T	P	Credits
ME535	Computational Fluid Dynamics	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The main objective of studying this course is to develop an understanding for the major theories, approaches and methodologies used in CFD. It also aims to build up the skills in the actual implementation of CFD methods in using commercial/Open Source CFD codes that helps to gain experience in the application of CFD analysis to real engineering designs.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Distinguish between finite difference, finite volume and finite element methods applied to fluid flow and heat transfer problems
CO2. Perform grid generation, and assess stability and conduct a grid-convergence assessment
CO3. Apply turbulence models, compressible flow solvers, and understand the issues surrounding two-phase flow modelling
CO4. Solve a heat transfer problem numerically
CO5. Demonstrate competence in using a commercial/Open Source CFD codes to an acceptable standard for a graduate engineer.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	H	M	M					H			
CO3	H	H	M	M					H			
CO4	H	H	M	H					H			
CO5	H	H	H	H					H			

Syllabus

Equations of fluid dynamics: Basic concepts Eulerarian and Lagrangian methods of describing fluid flow motion, acceleration and deformation of fluid particle, vorticity. Laws of governing fluid motion, continuity, Navier – stokes & energy equations. Boundary layer equation, Euler equations, potential flow equations, Bernoulli's equation and vorticity transport equation. Initial and boundary conditions. Classification of equation of motions – hyperbolic, parabolic, elliptic.

Mathematical Preliminaries: Numerical integration. Review of linear algebra, solution of simultaneous linear algebraic equations – matrix inversion, solvers – direct methods, elimination methods, ill conditioned systems; Gauss- Sidel method, successive over relaxation method.

Grid Generation: Transformation of co-ordinates. General principles of grid generation – structured grids in two and three dimensions, algebraic grid generation, differential equations based grid generation; Elliptic grid generation, algorithm, Grid clustering, Grid refinement, Adaptive grids, Moving grids. Algorithms, CAD interfaces to grid generation. Techniques for complex and large problems: Multi block methods.

Finite difference discretization: Elementary finite difference coefficients, basic aspects of finite difference equations, consistency, explicit and implicit methods, errors and stability analysis. Stability of elliptic and hyperbolic equations. Fundamentals of fluid flow modeling-conservative property, upwind scheme, transporting property, higher order up-winding. Finite difference applications in heat transfer – conduction, convection.

Finite Volume Method: Introduction, Application of FVM in diffusion and convection problems, NS equations – staggered grid, collocated grid, SIMPLE, SIMPLEC and SIMPLER algorithms, Solution of discretized equations using TDMA. Discretization for multi-dimensional diffusion problems, Stability analysis of parabolic and hyperbolic equation, FTCS, FTFS, FTBS, schemes, Convection-diffusion problems: Central difference, upwind schemes, exponential, hybrid and power-law schemes, QUICK scheme, Concept of false diffusion Finite volume methods for unsteady problems – explicit schemes, implicit schemes.

Finite Element Method: Introduction. Weighted residual and variational formulations. Interpolation in one-dimensional and two-dimensional cases. Application of FEM to 1D and 2D problems in fluid flow and heat transfer.

References/Text Material:

1. J. D. Anderson, Jr., "Computational Fluid Dynamics: The Basics with Applications," McGraw Hill Education, 2017.
2. H. K. Versteeg and W. Malalasekera, "An Introduction to Computational Fluid Dynamics: The Finite Volume Method," PHI, 2nd Ed., 2007.
3. S. V. Patankar, "Numerical Heat Transfer and Fluid Flow," CRC Press, 2017.
4. K. Muraleedhar and T. Sundararajan, "Computational Fluid Flow & Heat Transfer," Alpha Science International Ltd, 2nd Ed., 2003.
5. H. H. Fergiger and M. Peric, "Computational Methods for Fluid Dynamics," Springer, 2003.
6. P. J. Roache, "Fundamentals of Computational Fluid Dynamics," Hermosa, 2nd Ed., 1982.
7. R. W. Lewis, P. Nithiarasu, and K. N. Seetharamu, "Fundamentals of the Finite Element Method for Heat and Fluid Flow," John Wiley & Sons, Ltd, 2004.

Course Code	Course Name	L	T	P	Credits
ME536	**Finite Element Methods**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
The course aims to provide with a comprehensive understanding of the principles, techniques, and applications of finite element analysis in the field of engineering.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Explain finite element analysis fundamentals
- **CO2.** Apply numerical methods to physical problems
- **CO3.** Develop competence in element types and discretization
- **CO4.** Demonstrate proficiency of computer programs in solving different mechanical problems

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H				H				M			
CO2	H	H		H	H				M			
CO3	H	H	H	H	H				M			
CO4	H	M	H	H	H				M			

Syllabus

Introduction: General description, advantages, applications, overview of commercial finite element program packages, review of matrix algebra, numerical methods for solving linear systems of equations.

Basic Procedure in FEM: Element types, discretization procedure, interpolation models, description of direct method, variational approach, energy method, and weighted residual method.

Formulation: Derivation and assembly of element matrices and vectors for spring, bar, truss, beam, triangular, quadrilateral, and tetrahedral elements.

Applications: Solid mechanics problems, heat transfer problems, and fluid mechanics problems, computer implementation.

References/Text Material:

1. D. L. Logan, "First Course in the Finite Element Method," Cengage Learning, 2022.
2. P. Seshu, "Textbook of Finite Element Analysis," PHI Learning Pvt. Ltd., 2003.
3. S. S. Rao, "The Finite Element Method in Engineering," Butterworth-Heinemann, 2017.
4. O. C. Zienkiewicz, R. L. Taylor, and J. Z. Zhu, "The Finite Element Method: Its Basis and Fundamentals," Elsevier, 2005.

OPEN ELECTIVES

Course Code	Course Name	L	T	P	Credits
ME600	Microelectromechanical Systems	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
The course objective is to impart knowledge and skills in the design, fabrication, and application of Micro Electro Mechanical Systems (MEMS), exploring miniaturized devices with integrated mechanical and electrical components for diverse technological applications.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Appreciate the technologies related to Micro Electro Mechanical Systems.
- **CO2.** Understand various application areas for MEMS device using relevant mechanical/electrical/fluidic engineering principle.
- **CO3.** Illustrate various sensors and actuators.
- **CO4.** Gain comprehensive perspective of various fabrication processes and materials used in Microfabrication.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	H							M			
CO3	H	H	H	H					M			
CO4	H	H							M			

Syllabus

MEMS and Micro integrated Systems: Introduction, Definition of MEMS, Silicon as a MEMS material – mechanical properties of silicon, Mechanical components in MEMS, history of MEMS development, intrinsic characteristics of MEMS. Devices: Sensors and Actuators. Overview of microfabrication, microelectronics fabrication process, silicon-based MEMS processes, new materials and fabrication processes. Points of consideration for processing.

Scaling Laws and Miniaturization: Introduction. Scaling in geometry. Scaling in rigid body dynamics. The trimmer force scaling vector – scaling in electrostatic forces, electromagnetic forces, scaling in electricity and fluid dynamics, scaling in heat conducting and heat convection.

MEMS Processing: Materials for MEMS and Microsystems, fabrication technologies - Photolithography. Photoresist and applications. Light sources. X-ray and electron beam lithography. Ion implantation. Diffusion process. Oxidation, thermal oxidation. Silicon di oxide. Thermal oxidation rates. Oxide thickness by colour

Piezoresistive Sensors: Piezoresistive Sensor Materials, Stress Analysis of Mechanical Elements, Applications of Piezoresistive Sensors.
Piezoelectric Sensing and Actuation: Introduction, Properties of Piezoelectric Materials, Applications

Micromachining Methods: Bulk micromachining, Isotropic and anisotropic etching, Wet etchants, etch stops, dry etching comparison of wet and dry etching. Dry etching, physical etching, Deep Reactive Ion Etching(DRIE), comparison of wet and dry etching, Gas-Phase Etchants, Native Oxide, Wafer Bonding, Case Studies.

Surface micromachining: Basic Surface micromachining process in general, problems in surface micromachining, Structural and Sacrificial Materials, Acceleration of Sacrificial Etch, Stiction and AntiStiction Methods, The LIGA process, description, materials for substrates and photoresists, electroplating, the SLIGA process.

Polymer MEMS: Introduction, Polymers in MEMS-Polyimide, SU-8, Liquid Crystal Polymer (LCP), PDMS, PMMA, Parylene, Fluorocarbo, Representative Applications-Acceleration Sensors, Pressure Sensors, Flow Sensors, Tactile Sensors.

Optical MEMS: Passive MEMS Optical Components-Lenses, Mirrors, Actuators for Active Optical MEMS Actuators for Small Out-of-Plane Translation, Actuators for Large InPlane Translation Motion, Actuators for Out-of-Plane Rotation

Micro System Packaging: The three levels of microsystem packaging – die level, device level and system level. Essential packaging technologies – die preparation – surface bonding, wire bonding and sealing. Three-dimensional packaging. Assembly of Microsystems – selection of packaging materials

References/Text Material:

1. T.-R. Hsu, "MEMS and Microsystems Design and Manufacture," Tata McGraw-Hill Publishing Co Ltd, New Delhi, 2002.
2. J.J. Allen, "MEMS Design," CRC Press, 2010.
3. C. Liu, "Foundations of MEMS," Pearson International Ed., 2006.
4. M. Madou, "Fundamentals of Microfabrication," CRC Press, New York, 1997.
5. J.W. Gardner, V.K. Varadan, O.O. Awadelkarim, "Micro Sensors MEMS and Smart Devices," John Wiley & Sons Ltd, 2002.
6. S.D. Senturia, "Microsystem Design," Springer, 2000.

Course Code	Course Name	L	T	P	Credits
ME601	**Nonlinear Dynamics**	**3**	**0**	**0**	**3**

Credit: 3
Contact Hours (L-T-P): 3-0-0

Overlaps with: Nil
Couse Assessment Method: Tutorials, Quizzes, Programming Assignments, and Written Exams

Course Objective

The aim of this course is to cultivate a deep understanding of concepts in dynamical systems, including phase space, stability, and Poincaré maps. Exploring fundamental theorems such as Poincaré-Lyapunov and Hartmann-Grobmann, the course delves into perturbation theory, applications in both ODEs and PDEs, chaos, fractals, and nonlinear wave equations, equipping students to comprehend and analyze complex dynamical behaviors in a variety of systems.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Understand concepts like phase space, fixed points, and stability in dynamical systems.

CO2. Apply Poincaré-Lyapounov, Hartmann-Grobmann theorems to analyze system dynamics with a focus on fixed points.

CO3. Apply and analyze perturbation theory techniques, including secular terms and Gronwall lemma, for error estimation in approximation methods.

CO4. Analyze and solve ODEs and PDEs, exploring applications such as Duffing oscillator, nonlinear diffusion, and chaotic systems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H											M
CO2	H	H										
CO3	H	H	H									
CO4	H	H		H								

Syllabus

Concepts in dynamical systems: phase space, fixed points, stability, Poincaré map etc.

Basic theorems in system dynamics: Poincaré-Lyapounov, Hartmann-Grobmann, Center Manifold, Review of KAM Theorem.

Perturbation theory: secular terms, resonance in perturbation theory, Gronwall lemma, error estimation in approximation methods.

Applications in ODE's: Duffing oscillator, forced oscillations, limit cycles; Lorentz equations.

Applications in PDE's: nonlinear diffusion; amplitude equations, nonlinear wave equations - Burgers, KdV & NLS equations and their wave solutions, solitons, compactons.

Chaos: The logistic equations and the route to Chaos.

Fractals: Fundamental concepts in Fractals and Chaos.

Nonlinear wave equations

References/Text Material:

1. S.H. Strogatz, "Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering," 2nd ed., CRC Press, 2014.
2. A. Nayfeh, "Perturbation Methods," Wiley, 1978.
3. J.M.T. Thompson and H.A. Stewart, "Nonlinear Dynamics and Chaos: Geometrical Methods for Engineers and Scientists," 2nd ed., CRC Press, 2002.
4. A.H. Nayfeh and B. Balachandran, "Applied Nonlinear Dynamics: Analytical, Computational, and Experimental Methods," John Wiley & Sons, 2008.
5. F.C. Moon, "Chaotic and Fractal Dynamics: An Introduction for Applied Scientists and Engineers," John Wiley & Sons, 2013.
6. E. Ott, C. Grebogi, and J.A. Yorke, "Controlling Chaos: Theoretical and Practical Methods in Nonlinear Dynamics," Cambridge University Press, 1994.
7. J. Guckenheimer and P. Holmes, "Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields," Springer, 1983.
8. S. Wiggins, "Introduction to Applied Nonlinear Dynamical Systems and Chaos," Springer-Verlag, NY, 1992.
9. A.J. Lichtenberg and M.A. Lieberman, "Regular and Chaotic Dynamics," Springer-Verlag, NY, 1992.
10. B.L. Hao, "Chaos," World Scientific, Singapore, 1984.
11. P.B. Kahn and Y. Zarmi, "Nonlinear Dynamics – Exploration Through Normal Forms," Wiley, NY.

Course Code	Course Name	L	T	P	Credits
ME602	Artificial Intelligence in Engineering	3	0	0	3

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The course aims to provide a comprehensive understanding of artificial intelligence, expert systems, fuzzy logic, genetic algorithms, neural networks, and their fusion for solving manufacturing engineering problems through case studies. Students will gain proficiency in applying these advanced techniques to address real-world challenges.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the role and significance of artificial intelligence in the manufacturing industry, including its evolution and potential applications.
- **CO2.** Explore the components and functions of knowledge base expert systems and their relevance in solving manufacturing-related problems.
- **CO3.** Gain knowledge of fuzzy logic principles and its application in handling uncertainty and making informed decisions in manufacturing processes.
- **CO4.** Illustrate genetic algorithms and their ability to optimize solutions for complex manufacturing problems with multiple constraints.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								H			
CO2	H	M	M	H					H			
CO3	H	L	M	M					H			
CO4	H	M	M	H	H				H			

Syllabus

Overview of artificial intelligence: Introduction to AI, evolution of AI, application areas, advantages, limitations, future applications.

Knowledge base expert systems: Introduction, expert system components and human interfaces, expert system characteristics and features, knowledge acquisition, knowledge base, inference engine, forward chaining, backward chaining, expert system shell, explanation.

Fuzzy logic: Introduction, Sources of Uncertainty, Membership Functions and Uncertainty, type I and II fuzzy logic systems, application of fuzzy logic to manufacturing engineering problems.

Genetic algorithms: Introduction, random heuristic search, simple genetic algorithm (SGA): algebra, selection, mutation, crossover, mixing, application of SGA for solving single objective multi constraint problems.

Artificial neural networks: Introduction, supervised and unsupervised neural networks, single and multilayered neural networks, applications, advantages, drawbacks.

Introduction to Fusion of ANN, fuzzy and GA.

Case studies: Based on total number of students opting for this course, students will be appropriately grouped and asked to select problems from manufacturing engineering to solve them using the learnt techniques.

i. Learning of expert system software like VIDWAN, CLIPS and its application to make a decision support system to solve manufacturing engineering problems like, selection of tool characteristics based on application, selection of manufacturing systems, and advance machines.
ii. Application of fuzzy logic for selection of layered manufacturing systems, fluid flow control and temperature control systems.
iii. Application of GA for solving scheduling and cellular manufacturing.
iv. Modeling and application of ANN to manufacturing problems like optimal parameter selection for drilling, milling, EDM etc.

References/Text Material:

1. S. Rajashekaran and G.A.V. Pai, "Neural Networks, Fuzzy Logic & G.A. Synthesis & Application," 1st Ed., PHI, 2012.
2. K. Deb, "Genetic Algorithms," Wiley, 2010.
3. D.E. Goldberg, "Genetic Algorithms in Search, Optimization, and Machine Learning," Pearson Education India, 1992.
4. T.J. Ross, "Fuzzy Logic with Engineering Applications," John Wiley, 2010.
5. S. Kumar, "Neural Networks: A Classroom Approach," Tata McGraw-Hill Education, 2004.

Course Code	Course Name	L	T	P	Credits
ME603	**Computer Integrated Manufacturing**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course objective
This course builds to understand the gap between Computer aided design and manufacturing such that it transform basic manufacturing knowledge into advanced techniques of manufacturing

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Gain details of various elements of CIM
- **CO2.** Understand the concept of Numerical control and perform part programming
- **CO3.** Know the various computer aided manufacturing, material handling and storage system

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H					M	M			M	M	
CO2	M			M	H	M	M			H	M	L
CO3	M	H	M	M	M	M			H	H	M	H

Syllabus

Introduction to CIM: CIM evaluation, hardware and software of CIM, concurrent engineering, advance modeling techniques.

Numerical Control: Concepts and features, Classification, Input media, Design considerations, Functions of MCU, CNC concepts, Point-to-point and Contouring systems, Interpolators, Feedback devices, DNC, Adaptive Control, ACO and ACC systems.

Part programming: Manual part programming, preparatory, miscellaneous functions, computed aided part programming, post processors, programming.

Manufacturing: Cellular manufacturing, Group Technology, Flexible Manufacturing Systems Configurations, Workstations, Control systems, Applications and benefits

Materials handling and Storage Systems: Types of material handling systems, storage systems, Automated storage and retrieval systems, Robotics technology-control systems, Programming, Applications, Automated inspection and testing, Coordinate measuring machines

Project work based on above topics to be provided for assessment

References/Text Material:

1. P. Ranky, "Computer Integrated Manufacturing," Prentice Hall, 2005.
2. Y. Koren, "Computer Control of Manufacturing Systems," McGraw Hill Book Co., New Delhi, 1986.
3. M.P. Groover, "Automation, Production Systems and Computer Integrated Manufacturing," Prentice Hall, 2007.
4. D.T. Ijunclis and K.E. Mekie, "Manufacturing High Technology Handbook," Marcel Decker.

Course Code	Course Name	L	T	P	Credits
ME604	**Industrial Safety**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to educate participants on the evolution and implementation of modern safety concepts, covering areas such as safety policies, accident prevention, machine guarding, chemical safety, fire safety, and relevant regulatory acts.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the evolution of modern safety concepts, policy, organization, and budgeting, emphasizing the importance of safety in the workplace.
- **CO2.** Create a culture of safety through awareness programs, awards, posters, displays, and campaigns to promote safe practices and behaviors.
- **CO3.** Implement principles of accident prevention, including reporting, investigation, analysis, and documentation, to reduce accidents and their associated costs.
- **CO4.** Ensure machine guarding and safety measures in welding, gas cutting, material handling, and electrical usage. Address chemical hazards and implement control measures to protect workers' health.
- **CO5.** Enhance fire safety awareness by understanding the fire triangle, types of fires, firefighting equipment, flammability limits, and implementing proper safety measures, especially regarding LPG usage.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								L			
CO2	H		L	M		H	M	M	M			
CO3	H	M							M			
CO4	H	M		M					M			
CO5	H	M		M					M			

Syllabus

Introduction: Evolution of modern safety concept, safety policy, Safety Organization, Safety Committee, budgeting for safety.

Safety training: Creating awareness, awards, celebrations, safety posters, safety displays, safety pledge, safety incentive scheme, safety campaign

Accident: Concept of an accident, reportable and non-reportable accidents, reporting to statutory authorities, principles of accident prevention, accident investigation and analysis, records for accidents, departmental accident reports, documentation of accidents, unsafe act and condition, domino sequence, supervisory role, cost of accident.

Machine Guarding: Machine Guarding, guarding of hazards, Machine Guarding types and its application, Safety in welding and Gas cutting, Safety in Manual and Mechanical material handling, Safety in use of electricity.

Chemical Safety: Toxicity, TLV, Types of Chemical Hazards, Occupational diseases caused by dust, fumes, gases, smoke and solvent hazards, control measures.

Fire Safety: Fire triangle, Types of fire, first aid firefighting equipment, flammability limit, LPG safety

Acts: Overview of factories act 1948 – OHSAS-18000

References/Text Material:

1. "Accident Prevention Manual for Industrial Operations," 1982.
2. R.B. Blake, "Industrial Safety," Prentice Hall, Inc., New Jersey, 1973.
3. H.W. Heinrich, "Industrial Accident Prevention," McGraw-Hill Company, New York, 1980.
4. N.V. Krishnan, "Safety Management in Industry," Jaico Publishing House, Bombay, 1997.
5. J.R. Ridley, "Safety at Work," Butterworth & Co., London, 1983.

Course Code	Course Name	L	T	P	Credits
ME605	**Lean Manufacturing**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to equip participants with the principles and tools of lean manufacturing, emphasizing value creation, waste elimination, standard work, visual controls, and continuous improvement for efficient, quality-focused production processes. Students will learn to apply techniques such as Value Stream Mapping, JIT, Kanban, and team establishment to optimize production and enhance overall operational performance.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Grasp and apply fundamental principles of lean manufacturing to create value, eliminate waste, implement pull production, drive continuous improvement, involve workers, and optimize administrative processes.
- **CO2.** Implement standardized work procedures, visual controls, quality assurance at the source, 5S methodology, and preventive maintenance to enhance quality, efficiency, and safety.
- **CO3.** Analyze and optimize processes through value stream mapping, balance workloads, improve overall equipment effectiveness, and establish a seamless flow to minimize waste and enhance productivity.
- **CO4.** Gain insights into Just-in-Time (JIT) manufacturing, including pull systems, Kanban, small batch production, rapid setup, and ongoing improvement, to achieve efficient and responsive production.
- **CO5.** Foster effective teamwork, employ project management techniques, and integrate lean principles with Lean Six Sigma, ERP systems, and ISO 9001:2000 to drive successful lean implementation and continuous improvement.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	M							H			
CO2	H	H	M	M					M			
CO3	H	H	M	M					M			
CO4	H	M							M			
CO5	H		M	L					H			

Syllabus

Objectives of lean manufacturing: Key principles and implications of lean manufacturing-. Value creation and waste elimination, main kinds of waste, pull production, different models of pull production continuous flow, continuous improvement/Kaizen- worker involvement, cellular layout, administrative lean.

Standard work: communication of standard work to employees, standard work and flexibility, visual controls, quality at the source, 5S principles, preventative maintenance, total quality management, total productive maintenance, changeover/setup time, batch size reduction, production levelling.

Value Stream Mapping: The as-is diagram-the future state map, application to the factory simulation scenario, line balancing, Poke Yoke, overall equipment effectiveness. One Piece Flow, Process razing techniques, cells for assembly line, case studies

Introduction: Elements of JIT, uniform production rate, pull versus push method Kanban system, small lot size, quick, inexpensive set-up, continuous improvement. Optimized production technology.

Team establishment: Transformation process, Project Management, Lean implementation, Reconciling lean with other systems, lean six sigma, lean and ERP lean with ISO 9001:2000.

References/Text Material:

1. R.G. Askin and J.B. Goldberg, "Design and Analysis of Lean Production Systems," John Wiley and Sons Inc., 2003.
2. D.P. Hobbs, "Lean Manufacturing Implementation," Narosa Publisher, 2004.
3. M. Wader, "Lean Tools: A Pocket Guide to Implementing Lean Practices," Productivity and Quality Publishing Pvt. Ltd., 2002.
4. M.L. George, D.T. Rowlands, and B. Kastle, "What is Lean Six Sigma," McGraw Hill, New York, 2004.

Course Code	Course Name	L	T	P	Credits
ME606	**Product Design for Engineers**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to impart knowledge on product design fundamentals, development processes, and concept generation, guiding participants through the selection and testing phases while addressing product architecture, industrial design, and prototyping considerations. Students will gain insights into essential factors influencing design decisions and learn to navigate the primary design phases for effective product development.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand the fundamentals of product design, strategies and analysis
- **CO2.** Explain human considerations and modern approaches in product design
- **CO3.** Discuss about concept generation, selection, and testing
- **CO4.** Elucidate the concepts of reverse engineering and rapid prototyping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H			M					M			
CO3	H	M	M	M					M			
CO4	H	M		M					M			

Syllabus

Introduction: Definition of product design, Design by evolution and Design by innovation, Essential factors, Morphology of design, Primary design phases and flow charting

Product Development: History of Product Development, Development Processes and Organizations, Product Planning Identifying Customer Needs, Product Specification

Concept Generation: The activity of concept generation, clarify the problem, search externally, search internally, explore systematically, reflect on the results and the process. Concept Selection, Overview of methodology, concept screening, and concept scoring

Concept Selection and Testing: Define the purpose of concept test, choose a survey population, choose a survey format, communicate the concept, measure customer response, interpret the result, reflect on the results and the process

Product Architecture, Industrial Design, Prototyping: Virtual and Physical. Rapid Prototyping Technologies, Economic factors influencing Design

References/Text Material:

1. Ulrich and Eppinger, "Product Design and Development," Tata McGraw Hill, 2005.
2. K. Otto and K. Wood, "Product Design," Pearson Education, Inc., 2001.
3. Chitale and Gupta, "Product Design and Manufacturing," PHI, 2005.
4. K.G. Cooper, "Rapid Prototyping Technology," Marcel Dekker, Inc., 2001.
5. D.T. Pham and S.S. Dimov, "Rapid Manufacturing," Springer-Verlag, 2001.
6. H. Boothroyd, P. Dewhurst, W.A. Knight, "Product Design for Manufacture and Assembly," Marcel Dekker Inc., New York, 2010.
7. G. Pahl, W. Beitz, W. Feldhusen, J. Grote, "Engineering Design," Springer, 2007.

Course Code	Course Name	L	T	P	Credits
ME607	Quality Control and Reliability	3	0	0	3

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to provide a comprehensive understanding of quality assurance, control, statistical concepts, and tools, covering control charts, process capability, reliability analysis, safety measures, and fire protection for ensuring product quality and workplace safety. Students will acquire the knowledge and skills necessary to implement effective quality and safety practices across diverse industries.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Identify and analyze failures of components and subcomponents of mechanical and electronic items

CO2. Distinguish different concepts in maintenance and explore in order to increase service life of the products/machines

CO3. Enumerate various safety measures concerned with environment described for a safety engineer

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H	H		M					M			
CO2	H	M		M					M			
CO3	H	M	M	M					M			

Syllabus

Introduction: Introduction to quality assurance and quality control, Statistical concepts in quality, Central limit theorem, Quality control tools

Control Charts: Control charts for variables and attributes, process capability studies, Sampling Inspection, Quality System standards

Reliability: Reliability, Failure Rate, Mean Time Between Failures (MTBF), Mean Time To Failure (MTTF), Bathtub curve, analysis using exponential, normal and Weibull distribution, system reliability, Series, Parallel, complex structures, Redundancy, Reliability Allocation, Mechanical Reliability, Fault tree analysis, Down time, Repair time, maintainability, Availability, Failure Mode and Effect Analysis.

Safety: Importance of Safety, Fundamental Concepts and Terms, Workers' Compensation, Product Liability, Hazards and their Control, Walking and Working Surfaces, Electrical Safety -Tools and Machines, Materials Handling.

Fire Protection and Prevention: Explosions and Explosives, Radiation, Biohazards, Personal Protective Equipment, Managing Safety and Health

References/Text Material:

1. David J Smith, Butterworth-Heinemann, “Reliability Maintainability and Risk; Practical methods for engineers”, New Delhi, 2001
2. E.L.Grant and Leavenworth, “Statistical Quality Control”, McGraw-Hill Inc, Sixth Ed., 1988.
3. Charles E Ebeling “An Introduction to Reliability and Maintainability Engineering”
4. B.S. Dhillon, “Maintainability, Maintenance and Reliability for Engineers”, CRC Press, 2006
5. Roger L. Brauer, “Safety and Health for Engineers”, John Wiley Sons, 2006
6. Hoang Pham, “Handbook of Reliability engineering”, Springer Publication, 2003
7. B.S. Dhillon, “Engineering maintenance; a modern approach”, CRCPress, 2002

Course Code	Course Name	L	T	P	Credits
ME608	**Supply Chain Management**	**3**	**0**	**0**	**3**

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Nil
Course Assessment Method: As per Academic Rule Book

Course Objective

The course aims to equip participants with a comprehensive understanding of supply chain management, covering its objectives, processes, drivers, obstacles, and advanced topics such as green, lean, sustainable, global, and agile supply chain management.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand supply chain principles, stages, flows, and strategic decision-making for effective management.
- **CO2.** Evaluate supply chain performance using service, inventory, speed, and financial metrics and analyze the impact of drivers like inventory, transportation, facilities, and information.
- **CO3.** Design an optimized supply chain configuration through sourcing, alliances, outsourcing, facility location, and capacity allocation, using modeling and simulation for evaluation.
- **CO4.** Develop forecasting models and employ aggregate planning strategies to mitigate the bullwhip effect and optimize inventory management across the supply chain.
- **CO5.** Assess the role of transportation, packaging, pricing, and IT infrastructure in supply chain operations and employ coordination mechanisms to manage uncertainty and minimize the bullwhip effect.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	H	M	M					M			
CO3	H	H	H	M					M			
CO4	H	H	H	M					M			
CO5	H	H	M	M	L				M			

Syllabus

Understanding the Supply Chain, Performance, Drivers and Obstacles: objectives of supply chain (SC), Stages of supply chain, Supply chain process cycles, Push/pull view of supply chain processes, Importance of supply chain flows, Examples of supply chain, Strategic decisions in supply chain management. Supply Chain Performance, Supply chain strategies, Achieving strategic fit, Product life cycle, Supply Chain drivers and Obstacles, Four drivers of supply chain – inventory, transportation, facilities, and information, Obstacles to achieve strategic fit, Service Metrics, Inventory Metrics, Speed Metrics, Financial micro Metrics, Bullwhip Metric, Bad Metrics, Trade-off Curves, The Bullwhip Effect, Outsourcing

Supply chain configuration design: Factors involved, sourcing, models for strategic alliances, supplier selection, outsourcing and procurement process, facility location and capacity allocation, modeling approaches LP, MILP, network design in uncertain environment, evaluation using simulation models.

Demand forecasting: Role of forecasting in supply chain, Time series forecasting methods, Measures of forecast errors, collaborative forecasting models, bullwhip effect, information sharing, aggregate planning in supply chain, strategies, multi echelon inventory planning, models, discounting, risk pooling, centralized versus decentralized systems.

Roles of transportation: tradeoffs in transportation design, modes of transportation and their design, vehicle routing and scheduling, models, packaging, pricing and revenue management.

Role of IT in supply chain: IT infrastructure, CRM, SRM, e-business, RFID, supply chain collaboration, Decision Support System (DSS) for supply chain, selection of DSS for supply chain.

Managing Economies of Scale in a Supply Chain: Role of cycle inventory in a supply chain, various costs associated with inventory management, deterministic models and discounts, probabilistic inventory management, Safety Inventory.

Coordination in SC: Modes of Transportation and their performance characteristics, Supply Chain IT framework, Coordination in a SC and Bullwhip Effect

Advanced topics in SCM: Green, Lean, Sustainable, Global and Agile supply chain Management, Quality in Supply Chain.

Case Study: National and International case studies in a supply chain. its performance, drivers, and its metrics; Design of the supply chain network, Planning demand and supply in a supply chain, Planning and managing inventories in a supply chain, Designing and planning transportation networks, Managing cross-function drivers in a supply chain, Bullwhip effect.

References/Text Material:

1. S. Chopra and P. Meindel, "Supply Chain Management: Strategy, Planning, and Operation," 6th ed., Pearson Education, 2016.
2. C. Martin, "Logistics and Supply Chain Management," Pearson Education Asia, 2004.
3. M. Christopher, "Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Services," 1st ed., Pearson Education, 1998.
4. D. Simchi-Levi, P. Kaminsky, and E. Simchi-Levi, "Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies," 3rd ed. Revised, McGraw-Hill/Irwin, 2008.
5. J.F. Shapiro, "Modeling the Supply Chain," 2nd ed., Wadsworth Publishing Co Inc., 2006.
6. J. Heizer, B. Render, C. Munson, and A. Sachan, "Operations Management," 12th ed., Pearson Education, 2017.

Course Code	Course Name	L	T	P	Credits
ME609	**Value Engineering**	**3**	**0**	**0**	**3**

Credit: 3
Contact hours (L-T-P): 3-0-0
Overlaps with: Production and Operations Management
Course Assessment Method: As per Academic Rule Book

Course Objective

The course aims to impart comprehensive knowledge of value engineering, covering concepts, functions analysis, techniques, cost evaluation, implementation, and management. Students will develop skills in applying various value engineering techniques to enhance product development, process improvement, and system design while fostering cost-effectiveness and innovation.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand concepts and applications for enhanced productivity. Recognize the role of Value Engineering in problem recognition and solution generation.
- **CO2.** Acquire skills in functional analysis techniques. Apply quantitative evaluation methods to generate alternate ideas and solutions.
- **CO3.** Develop skills in product and operation selection, optimal decision-making, and effective reporting.
- **CO4.** Understand cost elements, perform evaluation, and assess worth. Recognize the importance of worth in decision-making.
- **CO5.** Gain insights into managing Value Engineering and conducting savings audits.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								M			
CO2	H	M		H					M			
CO3	H		H	H					M			
CO4	H	M							M			
CO5	H	M	M						M			

Syllabus

Introduction: Value engineering concepts, advantages, applications in product development, process improvement, service improvement and system design, problem recognition, role in productivity

Analysis of Functions: Anatomy of function, use, antique, Types of functions, Level of function, Function identification, cost, esteem and exchange values, primary versus secondary versus tertiary/unnecessary functions, functional analysis: FAST (Function Analysis System Technique) and quantitative evaluation of ideas, case studies.

Value Engineering Techniques: Selecting products and operations for VE action, timing; VE programmes, determining and evaluating functions(s), assigning rupee equivalents, developing alternate means to required functions(s), decision making for optimum alternative, use of decision matrix, make or buy decisions, measuring profits, reporting results and follow up.

Cost and Worth: cost and price, elements of cost, need to calculate cost, Cost evaluation, case study methods of determining the cost, worth, Evaluation of worth, guidelines to find out worth, Importance of worth in the value engineering, metrology, discussion on worth.

Implementation: Action plan, record progress, report progress, review meetings, problems in implementation, human factors.

Managing VE: Level of VE in the organization, size and skill of VE staff, small plant VE activity management supports; Audit of savings.

Techniques – Brainstorming, The Gordon technique, Feasibility Ranking, the morphological analysis technique, ABC Analysis, probabilistic approach, Make or buy technique, Special techniques, function- cost- worth Analysis, Weighted Evaluation method, evolution matrix, Break even analysis, Life cycle cost Applications, team dynamics, team structure, team building, job plan, orientation phase, information phase, function phase creative phase, evaluation phase, recommendation phase, implementation phase, case study- detail case short case.

References/Text Material:

1. L. D. Miles, "Techniques of Value Analysis and Engineering," Eleanor Miles Walker, 1989.
2. R. J. Park, "Value Engineering: A Plan for Invention," St. Lucie Press, 1999.
3. J. V. Michaels and W. P. Wood, "Design to Cost," Wiley Interscience, 2004.
4. D. Younker, "Value Engineering: Analysis and Methodology," CCC/CVS, Winter Springs, Florida, USA, 2003.
5. T. R. King, "Value Engineering: Theory and Practice in Industry," CVS Lawrence D. Miles Foundation, 2000.
6. H. G. Tufty, "Compendium on Value Engineering," The Indo American Society, 1983.
7. Jagannathan, "Getting More at Less Cost," Tata McGraw Hill, 1992.
8. A. K. Mukhopadhyaya, "Value Engineering," 1st ed., SAGE Publications Inc, 2003.

Course Code	Course Name	L	T	P	Credits
ME610	**Engineering Optimization**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
The course aims to introduce and apply various optimization methods to single and multi-variable constrained problems.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Understand the fundamentals of optimization in design, problem formulation and classification.
CO2. Explore single and multi-variable optimization techniques, study constrained optimization methods.
CO3. Gain knowledge of evolutionary optimization algorithms, multi-objective optimization, and data-driven techniques in optimization, with case studies and computer implementation.
CO4. Solve single and multi-objective constrained optimization problems

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H								H			
CO2	H	M		H					H			
CO3	H	L		H					H			
CO4	H	H	H	H					H			

Syllabus

Introduction to optimization in design: Introduction to Engineering Design, Identification of Customer Requirements, Mapping Customer Requirements to Engineering Characteristics, Problem formulation, Optimization problems in Mechanical Engineering, Classification of methods for optimization.

Single-variable Optimization: Optimal criteria, Derivative-free methods (bracketing, region elimination), Derivative based methods, root-finding methods. Multiple-variable Optimization: Optimal criteria, direct search methods (Box's, Simplex, Hooke-Jeeves, Conjugate methods), Gradient-based methods (Steepest Descent, Newton's, Marquardt's, DFP method). Formulation and Case studies.

Constrained Optimization: KKT conditions, Penalty method, and Sensitivity analysis, direct search methods for constrained optimization, quadratic programming, GRG method, Formulation and Case studies.

Evolutionary Optimization algorithm: Genetic algorithms, simulated annealing, Anti-colony optimization, Particle swarm optimization. Multi-objective Optimization: Terminology and concepts, the concepts of Pareto optimality and Pareto optimal set, formulation of multi-objective optimization problem, NSGA, MOPSO.

Data-driven Techniques in Optimization: Machine Learning Methods (Decision Tree, KNN algorithm, Gradient boosting algorithm etc.). Case studies and Computer Implementation: Representative case studies for important methods and development of computer code for the same to solve problems.

References/Text Material:

1. S. S. Rao, "Engineering Optimization: Theory and Practice," New Age International, 3rd ed., 2013.
2. J. Arora, "Introduction to Optimum Design," Academic Press, 2004.
3. K. Deb, "Optimization for Engineering Design: Algorithms and Examples," PHI Learning, 2004.
4. Y. Jaluria, "Design and Optimization of Thermal Systems," CRC Press, 2nd ed., 2008.

Course Code	Course Name	L	T	P	Credits
ME611	**Alternate Fuels and Automotive Emission Control**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
The course aims to explore the various alternative fuels for internal combustion engines. It also aims to understand the modern emission control techniques and impact on the environment.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

- **CO1.** Understand fuel characteristics, combustion in IC engines, and the current global scenario of automotive fuels and explore the need for alternative fuels.
- **CO2.** Explore the various alternative fuels and fuel additives used in IC engines.
- **CO3.** Gain knowledge of modern automotive emission control systems, measurement of emissions, and advancements in exhaust after-treatment technologies.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H			M			H		M			
CO2	H	H	M	H			H		M			
CO3	H	M	M	H			H		M			

Syllabus

Fuels and Combustion: Fuel characteristics, Combustion in IC engines, Current global scenario of various automotive fuels, need for alternate fuels, ASTM standards of fuel testing.

Alternate fuels: Oils, Alcohols, Esters, Ethers, Hydrogen, Natural gas, LPG, and other alternate fuels and their sources. Fuel blends – emulsification, blends of conventional fuels, nanoparticle, and hydrocarbon additives.

Modern automotive emission control: Types and measurement of automotive emissions, combustion and emission characteristics, Advancement in engine designs, fuel modification, exhaust after treatment (Three-way catalyst, DOC, DPF, SCR, LNT, EGR, etc.).

References/Text Material:

1. S. S. Thipse, "Alternative Fuels," Jaico Publishing House, 2010.
2. A. K. Singh, D. Kumar, and A. K. Agarwal, "Alternative Fuels and Advanced Combustion Techniques as Sustainable Solutions for Internal Combustion Engines," Springer, 2021.
3. J. Halderman, "Automotive Fuel and Emissions Control Systems," Pearson, 4th ed., 2015.
4. W. A. Majewski and M. K. Khair, "Diesel emissions and their control," SAE, 2006.

Course Code	Course Name	L	T	P	Credits
ME612	**Energy Auditing and Management**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective
The objective of the course is to impart knowledge to master sustainable energy use through auditing, conservation strategies, and economic analysis for diverse systems.

Course Outcomes
At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Understand the importance of energy conservation and its role in sustainable development, Energy Conservation Act, and energy management programs.
CO2. Explore the concept of energy auditing, its need, types, and the energy economics and financial analysis techniques.
CO3. Analyze energy conservation strategies and performance evaluation methods for steam, electrical, and space heating/cooling systems.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H			M					M			
CO2	H	M	M	M					M			
CO3	H	H	M	M					M			

Syllabus

Energy Scenario: Introduction, energy problems, energy use trends in developing countries, prospects of changes in energy supply, strategies for sustainable development, finite fossil reserve, Energy and environment, Need for renewable and energy efficiency, Energy conservation principles.

Energy management: Definitions and significance, Two sides of energy management, Sectors of supply side energy management, Objectives of energy management, Hierarchical levels of supply side energy management, Trade-off between energy and environment, Energy and economy, energy management and control system (EMC's or EMS) for demand side, Energy management in end user plant, Seven principles of energy management, Energy policy of supply organization and demand side organization for energy management, Organization of energy management, Training and human resource development, motivation.

Energy Planning : Energy strategy, Energy policy and energy planning, Essential imperatives and steps in supply side energy planning, energy planning flow for supply side, Essential data for supply side energy planning, infrastructure planning, Transportation of energy, Per capita energy consumption, Essential imperatives and steps in user side energy planning, Energy policy of demand side organization (energy consumer).

Energy Audit: Introduction, Types of energy audits, energy audit, Intermediate energy audit, Comprehensive energy audit, End use energy consumption profile, Procedure of energy auditing, Composition of comprehensive auditing, Data for comprehensive audit, Site testing and management.

Energy Conservation and Recycling: Introduction, Listing of energy conservation opportunities, Electrical ECOs, Thermodynamic ECOs, ECOs in chemical processing industries, ECOs in medium and small industries, ECOs in residential buildings, shopping complexes and in university campus, Human and animal bio-muscle energy, Waste management, Recycling of discarded materials and energy recycling, Waste recycling management.

References/Text Material:

1. S. Rao and Dr. B. B. Parulekar, "Energy Technology (Non-Conventional, Renewable and Conventional)," Khanna Publications, 3rd Ed., 1994.
2. A. B. Gill, "Power Plant Performance," Standards Media, 2003.
3. I. G. C. Dryden, "The Efficient Use of Energy," Butterworth-Heinemann Ltd, 2nd ed., 1982.
4. J. Wood and B. F. Wollenberg, "Power Generation, Operations and Control," Wiley-Blackwell, 3rd Ed., 1984.

Course Code	Course Name	L	T	P	Credits
ME613	**Renewable Energy Systems**	**3**	**0**	**0**	**3**

Credit: **3**
Contact hours (L-T-P): **3-0-0**
Overlaps with: **Nil**
Course Assessment Method: **As per Academic Rule Book**

Course Objective

The course aims to navigate the evolving energy landscape with insights into renewables, environmental impacts, and cutting-edge technologies like hydrogen and fuel cells.

Course Outcomes

At the completion of this course, the student shall acquire knowledge and ability to -

CO1. Understand the current and future trends in the global energy scenario, implications of renewable energy options on the environment and society.

CO2. Gain knowledge of solar energy utilization, energy conversion from wind, biomass, and other renewables

CO3. Explore hydrogen energy and fuel cell technology

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	H						M		M			
CO2	H	L		M			M		M			
CO3	H	M	M	M			M		M			

Syllabus

Global energy scenario: current and future trends. Renewable energy options, environmental and social implications.

Solar Energy: Solar radiation, utilization of solar energy, different types of collectors and concentrators, photovoltaic applications.

Wind Energy: Wind resource assessment and characterization, wind energy conversion conversion devices – classification and applications, hybrid systems, safety and environmental aspects

Bioenergy: Biomass resources classification and characterization, thermochemical, biochemical, and hydrothermal processes for bioenergy conversion.

Hydrogen and fuel cells: Thermodynamics and electrochemical principles, basic design, types, and applications, production methods, principle of working and various types of fuel cells, construction, and applications.

Other renewables: Ocean thermal, geothermal, micro hydel, tidal and wave energy, magnetohydrodynamic power generation.

References/Text Material:

1. J. A. Duffie and W. A. Beckman, "Solar Engineering of Thermal Processes," John Wiley & Sons, 2013.
2. G. D. Rai, "Non-conventional Energy Sources," Khanna Publishers, 2007.
3. G. Boyle, "Renewable Energy: Power for a Sustainable Future," Oxford University Press, 3rd ed., 2012.