TRANSFORMS AND NUMERIAL TECHNIQUES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Course Code	:	23ME2301	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. **Apply** their knowledge of Laplace transforms and inverse Laplace transforms to proficiently solve linear ordinary differential equations with constant coefficients, facilitating the analysis and modelling of complex systems.
2. **Analyze** periodic functions using Fourier series, assessing the convergence properties and precision of the series expansion, thereby enhancing their ability to understand and manipulate periodic phenomena.
3. **Utilize** complex exponential form, Fourier transforms of basic functions, and Fourier sine and cosine transforms to solve problems involving Fourier integrals, developing proficiency in applying these techniques to various mathematical scenarios.
4. **Employ** numerical methods, including Euler's Method, Runge-Kutta 4th order, Adams-Bashforth, and Adams-Moulton Methods, to solve differential equations and effectively analyze dynamic systems, enabling them to model real-world phenomena and make accurate predictions.
5. **Apply** finite difference methods, including the Crank-Nicolson method and appropriate techniques for hyperbolic PDEs, to effectively solve different types of partial differential equations (PDEs) such as elliptic, parabolic, and hyperbolic equations, enhancing their problem-solving skills in the context of differential equations and their applications.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I: Laplace Transform and Inverse Laplace Transform	09 Hours
Laplace Transforms of Elementary functions (without proof), ***(Text Book-1: Chapter 6: 203 to 207).*** Laplace Transforms of $e^{at}f(t), t^n f(t)$ and $\frac{f(t)}{t}$, Periodic functions, Unit step function and impulse functions ***(Text Book-1: Chapter 6:208-230)***. Inverse Laplace Transforms- By the method of Partial Fractions, Logarithmic and Trigonometric functions, Convolution Theorem, Inverse Laplace transform using Convolution Theorem ***(Text Book-1: Chapter 6: 238)***. Solution to Differential Equations by Laplace Transform. ***(Text Book-1: Chapter 238-242)***.	

UNIT – II: Fourier Series	09 Hours
Periodic Functions, Trigonometric Series ***(Text Book-1: Chapter 11: 495).*** Fourier series Standard function, Functions of any Period 2L, Even and Odd functions, Half-range Expansions. ***(Text Book-1: Chapter 11: 483-492).*** Practical Harmonic analysis (calculate average power and RMS values of periodic waveforms)	

UNIT – III: Fourier Transform	06 Hours
Calculation of Fourier integrals using complex exponential form ***(Text Book-1: Chapter 11: 510).*** Fourier transform of basic functions ***(Text Book-1: Chapter 11: 510-516).*** Fourier sine and cosine transforms. ***(Text Book-1: Chapter 11: 518-522).***	

UNIT – IV: Numerical Methods for Solving Ordinary Differential Equations	07 Hours
Euler's Method-Basic principles of Euler's method for solving first-order ODEs ***(Text Book-1: Chapter 1:10-12).*** Runge-Kutta 4th order ***(Text Book-1: Chapter 21:904).*** Multistep Methods- Explanation of multistep methods (Adams-Bashforth, Adams–Moulton Methods) ***(Text Book-1: Chapter 21:911-913).*** Second-Order ODE. Mass–Spring System (Euler Method, Runge–Kutta Methods) ***(Text Book-1: Chapter 21:916-918).***	

UNIT – V: Numerical Methods for Partial Differential Equations	08 Hours
Classification of PDEs (elliptic, parabolic, hyperbolic), ***(Text Book-1: Chapter 21:922-923).*** Finite Difference Methods (Laplace and Poisson Equations), Derivation of finite difference approximations ***(Text Book-1: Chapter 21:923-927).*** Crank–Nicolson Method ***(Text Book-1: Chapter 21:938-941).*** Method for Hyperbolic PDEs ***(Text Book-1: Chapter 21:943-945).***	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply Laplace transforms and inverse Laplace transforms to solve linear ordinary differential equations with constant coefficients, demonstrating proficiency in system analysis and modelling.
2	Analyse periodic functions using Fourier series and evaluate the convergence properties and precision of the series expansion.
3	Solve problems involving Fourier integrals by applying complex exponential form, Fourier transforms of basic functions, and Fourier sine and cosine transforms.
4	Utilize numerical methods such as Euler's Method, Runge-Kutta 4th order, Adams-Bashforth, and Adams-Moulton Methods to solve differential equations and analyze dynamic systems
5	Apply finite difference methods, including the Crank-Nicolson method and appropriate techniques for hyperbolic PDEs, to solve various types of partial

	differential equations (PDEs) such as elliptic, parabolic, and hyperbolic equations.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	2	1	-	-	-	1	-	-	-	-	-
CO2	3	2	2	-	-	-	-	1	-	-	-	-	-
CO3	3	2	2	1	-	-	-	1	-	-	-	-	-
CO4	3	2	2	1	-	-	-	1	-	-	-	-	-
CO5	3	2	2	1	-	-	-	1	-	-	-	-	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Erwin Kreyszig, Advanced Engineering Mathematics, 2015, 10th Edition, Wiley India.

REFERENCE BOOKS:

1. Higher Engineering Mathematics, B.S. Grewal, 2015, 43rd Edition, Khanna Publishers.
2. Higher Engineering Mathematics, John Bird, 2017, 6 th Edition, Elsevier Limited.

E-Resources:

1. https://nptel.ac.in/courses/111106139
2. https://nptel.ac.in/courses/111101164
3. https://nptel.ac.in/courses/111105038

ENGINEERING MATERIALS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Course Code	:	23ME2302	**Credits**	:	03
Hours / Week	:	04 Hours	**Total Hours**	:	30+30 Hours
L–T–P–S	:	2–0–2–0			

Course Learning Objectives:

This course will enable students to:

1. **Analyse** the atomic/molecular structure difference between crystalline and non-crystalline materials.
2. **Determine** the tensile, compression, shear, and bending deformations of the metal specimen and describe the changes in specimen profile up to the point of fracture.
3. **Explain** the various phases present, composition, and mass fractions of the phases from a binary phase diagram.
4. **Understand** the types and applications of ceramics and polymers.
5. **Learn** the different manufacturing processes for composite materials.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of material testing of different metals and alloys

UNIT – I	05 Hours
INTRODUCTION TO MATERIALS: Introduction to materials, Overview of Crystal Structure, Solid Solutions, Hume Rothery Rules, Crystal Imperfections, Critical nucleus size, and Critical Free Energy. **CRYSTALLIZATION:** Mechanism of Crystallization, Nucleation, Nucleation- Growth, Single crystal, Polycrystalline Materials, Basic principles of solidification of metals and alloys. Solidification time, Cooling curves, Non- crystalline solids. functions	
UNIT – II	**05 Hours**
TESTING OF MATERIALS: Testing of materials under tension, compression, and shear loads, Hardness tests, fatigue, and creep test. Impact testing. **FATIGUE AND FRACTURE TEST:** Fatigue testing, Fracture, Types, Fracture mechanics. Characteristics of creep curve & steady-state creep. Fracture toughness &fatigue, Stress, and temperature effects.	
UNIT – III	**06 Hours**
EQUILIBRIUM PHASE DIAGRAMS: Particle strengthening by precipitation. Precipitation reactions. Phase Rule, Unary System, Binary Phase diagrams, and Iron-carbon system. **PHASE TRANSFORMATIONS.** Transformation rate effects and Isothermal transformations (TTT Curves), Continuous cooling transformations, Microstructure and property changes in the iron-carbon system, Iron-carbon equilibrium diagram, and Heat treatments.	
UNIT – IV	**05 Hours**
STEEL AND MATERIAL PROPERTIES: Classification of steels and cast iron, Microstructure, Effect of alloying elements on steel, Ferrous alloys, and their applications, High Resistivity and High-temperature alloys, Selection of material for various applications- case studies. **CERAMICS:** Ceramics, Glass Ceramics, Advanced Ceramics, Functional properties and applications of ceramic materials and Glasses.	
UNIT – V	**05 Hours**
OPTICAL PROPERTIES OF MATERIALS Electromagnetic radiation, light interaction with solids, atomic and electronic interaction, refraction, reflection, and absorption. Light-emitting diodes, lasers, and optical fibres in communication	
LAB COMPONENT	
1. Tension Test- To understand the tensile characteristics of mild steel through tensile testing and thereby determine mechanical properties such as ultimate tensile strength, elastic modulus, proportionality limit, yield point, fracture stress, percentage elongation & reduction in area. 2. Compression Test- To determine the compressive strength of aluminium and cast-iron specimens and to identify the failure modes of ductile/brittle materials through evaluation of their failure modes of the above material. 3. Shear Test - To determine the ultimate shear strength of aluminium under single and double shear.	

4. Bending Test - To investigate the relationship between load and span on the deflection of a simply supported beam Courseed to a concentrated load at the center. Also, evaluate the modulus of elasticity of the given beam from the test data.
5. Impact Test (Charpy and Izod) - To evaluate the energy absorbed during failure of a notched specimen Courseed to pendulum impact testing.
6. Brinell hardness Test -To determine the Brinell Hardness Number (BHN) of the given specimens.
7. Vicker's Hardness Test - To determine Vickers Hardness Number for a given specimen.
8. Wear Test - To understand the parameters that affect the wear rate using pin and disc apparatus.
9. Composite preparation- preparation of polymer composites through hand lay-up, vacuum bagging, and resin transfer molding process.
10. Demonstration of 3D printing of given polymer/metal/ceramic specimens

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply fundamental concepts of material science, including crystal structures, solid solutions, and crystallization mechanisms, to evaluate the mechanical properties of materials and also analyse fatigue behaviour under various loading conditions
2	Analyse equilibrium phase diagrams and phase transformations to understand and predict microstructure and property changes in materials, with a focus on the iron-carbon system and heat treatments.
3	Investigate the classification, microstructure, and properties of steels, cast irons, and ceramics to identify suitable materials for various engineering applications.
4	Investigate optical properties and interactions of materials to apply principles in developing LEDs, lasers, and optical fibres for communication.
5	Interpret various mechanical tests, including tension, compression, shear, bending, impact, hardness, and wear tests, as well as prepare and assess polymer composites

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	2	2	1	1	1	1	-	-	-	2	2
CO2	3	3	2	2	2	1	-	-	-	-	-	2	2
CO3	3	3	2	1	2	2	-	1	-	-	-	2	3
CO4	3	2	2	1	2	1	-	1	-	-	-	2	2
CO5	2	2	3	2	-	-	1	1	2	1	-	3	2

TEXT BOOKS:

1. William D. Callister, Jr. (2020) "Materials Science and Engineering an Introduction", 2nd Edition, John Wiley & Sons, Inc.

2. V. Raghavan (2019), "Materials Science and Engineering", Prentice–Hall of India Pvt. Ltd

REFERENCE BOOKS:

1. J.M. Shackelford (2014), Introduction to Materials Science for Engineers, 5th Edition, Prentice Hall, Inc.
2. Suryanarayana, A. V. K. (2020), Testing of Metallic Materials, Prentice Hall India, New Delhi.
3. W. Bolton (2013), Engineering materials technology, 3rd Edition, Butterworth & Heinemann.

E-Resources:

1. https://nptel.ac.in/courses/113107078
2. https://nptel.ac.in/courses/103105219
3. https://nptel.ac.in/courses/112107221
4. https://www.coursera.org/learn/crystal-structures-and-properties-of-metals?

Activity-Based Learning (Suggested Activities in Class)

1. Real-world problem-solving and puzzles using group discussion. E.g. material identification, microstructure study of materials using an Optical microscope, etc.,
2. Demonstration of the fabrication of material using different techniques like stir casting, Hand layup, etc.

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FLUID MECHANICS AND MACHINES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Course Code	:	23ME2303	**Credits**	:	04
Hours / Week	:	05 Hours	**Total Hours**	:	45+30 Hours
L–T–P–S	:	3–0–2–0			

Course Learning Objectives:

This Course will enable students to:

1. **Define** basic properties of fluids and understand the continuum approximation.
2. **Describe** Lagrangian and Eulerian Approach for fluid flow Buckingham's Pi theorem
3. **Apply** dimensional analysis to design new pumps or turbines that are geometrically similar to existing pumps or turbines
4. **To study** the performance parameters of Impulse and Reaction turbines like Pelton wheel turbine, Francis turbine and Kaplan turbine
5. **To study** the performance parameters of Reciprocating, Centrifugal and Gear pumps

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	**08 Hours**

Fluid Properties and Fluid Statics

Introduction, properties of fluids, viscosity, thermodynamics properties, surface tension and capillarity, vapour pressure. Types of fluid flows Fluid pressure at a point, Pascal's law, pressure variation in a static fluid, absolute, gauge, atmospheric and vacuum pressures, Fluid Statics: Fluid pressure at a point, Pascal's law, pressure variation in a static fluid.

UNIT – II	**08 Hours**

Fluid Kinematics and Dynamics

Lagrangian and Eulerian Approach for fluid flow, Continuity equation Velocity and acceleration in a flow field, Potential and stream function, **Fluid Dynamics**

Introduction, Equation of motion, Euler's equation of motion, and Bernoulli's equation derived from fundamental &Euler's equation, Bernoulli's equation for real fluids. Fluid Flow measurements-Venturimeter, orifice meter and Pitot tube. Flow through Pipes-Major & Minor losses in pipe flow. Numerical exercise. of large integers, ***(Text Book-2: Chapter 7: 7.1 to 7.6)***

UNIT – III	06 Hours

Dimensional Analysis and Boundary Layers

Introduction, Dimensional homogeneity –Buckingham theorem – Non-dimensional numbers – Model laws; Unit Quantities and Specific quantities, introduction to boundary layer theory – Laminar flow and Turbulent flow – Boundary layer thickness.

UNIT – IV	09 Hours

Hydraulic Turbines

Euler's Turbine equation, Classification of turbines, Impulse and reaction turbines, Pelton wheel, Francis and Kaplan turbine –work done and efficiencies. Draft tube theory, Performance of hydraulic machines, unit and specific quantities, turbine governing. The Knapsack problem

UNIT – V	08 Hours

Pumps

Classification, working, work done – monometric head- losses and efficiencies- specific speed-pumps in series and parallel-performance characteristic curves, NPSH. Reciprocating pumps: Working, Discharge, slip.

List of Laboratory/Practical Experiments activities to be conducted (if any) : 30Hrs

1. **Rotameter**
Calculation of the Rate of Flow Using Rotameter
2. **Venturimeter**
Determination of the Co- Efficient of Discharge of the Venturimeter
3. **Orifice Meter**
Determination of the Co-Efficient of Discharge of the Given Orifice Meter
4. **Pipe Friction**
Determination of frictional loss in a pipe flow
5. **Pipe Fittings**
Determination of Loss of Head on Pipe Fittings
6. **Notch**
Determination of Co- efficient of Discharge of the Given Notch
7. **Centrifugal Pump**
Study of Performance Test On Centrifugal Pump
8. **Reciprocating Pump**
Study of Performance Test On Reciprocating Pump
9. **Gear Pump Test Rig**
Study of Performance Test On Gear Pump
10. **Pelton Wheel Turbine**
Study of Performance Test on Pelton Wheel Turbine
11. **Francis Turbine**
Study of Performance Characteristics Curves of Francis Turbine

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

1	Analyse the rheological behaviour to classify fluids, and determine the pressure, velocity, and acceleration at a point in both static and moving fluids.
2	Apply Bernoulli's equation for a real fluid flowing between two sections for various engineering applications like measurement of discharge and estimation of losses
3	Develop non-dimensional groups for a physical phenomenon dependent on number of variables and also predict different flow regimes possible in case of a fluid -solid interaction based on Reynold's number
4	Calculate the power produced/ consumed and efficiencies obtained for a hydraulic machine by drawing the velocity triangles obtained from liquid and solid interaction
5	Compute the discharge, losses in a pipe flow and also predict performance of hydraulic machines for different operating conditions like varying load and discharge

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	2	1	3	-	-	-	-	-	-	-	3
CO2	3	2	2	2	2	-	-	-	-	-	-	-	3
CO3	3	3	1	3	2	-	-	-	-	-	-	-	3
CO4	3	3	3	2	2	-	-	-	-	-	-	-	3
CO5	3	3	3	3	2	-	-	3	2	1	-	-	3

Textbooks:

1. Lal, J. (2016). *Hydraulic Machines*. Metropolitan Book Company Limited.
2. Cengel, Y. A., & Cimbala, J. M. (2006). *Fluid Mechanics: Fundamentals and Applications*. Tata McGraw-Hill Publishing Co. Ltd.

Reference Books:

1. Munson, B. R., Young, D. F., Okiishi, T. H., & Huebsch, W. W. (2009). *Fundamentals of Fluid Mechanics*. John Wiley & Sons Publications.
2. White, F. M. (2011). *Fundamentals of Fluid Mechanics*. John Wiley & Sons Publications.

E-Resources:

1. https://open.umn.edu/opentextbooks/textbooks/85
2. https://library.iitd.ac.in/index.php/node/81851
3. https://www.constructionplacements.com/books-on-fluid-mechanics/
4. https://searchworks.stanford.edu/view/11842972

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MACHINING PROCESS AND METROLOGY

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Course Code	:	23ME2304	**Credits**	:	03
Hours / Week	:	04 Hours	**Total Hours**	:	30+30 Hours
L–T–P–S	:	2–0–2–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the basic fundamentals and mechanics of metal cutting, tool geometry and life.
2. Explain the basic knowledge of various non-traditional machining processes
3. Impart knowledge on CNC machining operation
4. Describe and illustrate the concept of slip gauges and wringing phenomenon and Study on different types of mechanical and electrical compactors
5. Study the limits, fits, tolerances and gauges.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I MODULE 1: Theory of Metal Cutting	**05 Hours**
Types of cutting tool materials, cutting fluids, Single & Multi point cutting tool nomenclature, orthogonal and oblique cutting, mechanism of chip formation, types of chip, merchant analysis, Ernst-merchant's solution, shear angle relationship, problem of merchant's analysis, tool wear and tool failure effects of cutting parameters, tool life criteria, Taylor's tool life equation, problems. . ***(Text Book-1: Chapter 1: 1.1 to 1.2)***	
UNIT – II: Non-Traditional Machining Processes	**05 Hours**
Introduction, Classification, Abrasive jet machining, Ultrasonic machining, Water jet	

machining, Abrasive Water Jet Machining, Electro chemical machining, Electro Chemical Grinding, Electro-discharge machining, Laser beam machining, Electron Beam Machining, Chemical Milling, Photochemical Milling process characteristics – applications, advantages and disadvantages.	
UNIT – III: Computer Numerical Control & Part Programming	**06 Hours**
Fundamentals of numerical control, advantages & classification of NC systems, Functions of MCU, principles of operation features, functions of CNC, Manual part programming, Codes and concepts, point to point and contour programming examples, 2-D simple problems of Drilling, Turning and Milling.	
UNIT – IV: Standards of Measurement in Metrology	**06 Hours**
Concept of metrology, role of standards, and standards of length Principles, calibration of standards, numerical problems, and slip gauges, set of gauges, wringing phenomena, manufacture of slip gauges. Numerical problems on building of slip gauges, Errors in measuring instruments, classification of errors, sources of errors and uncertainty. **Comparators** - mechanical, electrical, pneumatic and optical comparators **Advances in Metrology** Basic concept of lasers, laser Interferometers. Basic concept of CMM, Types of CMM.	
UNIT – V : System of Limits, Fits, Tolerance and Gauging	**04 Hours**
Indian standards, concept of limits of size and tolerances, interchange ability, selective assembly definition of fits, hole basis system, shaft basis system, types of fits and their designation, geometric tolerance. Classification of gauges, brief concept of design of gauges (Taylor's principles), Numerical problems.	
List of Laboratory/Practical Experiments activities to be conducted: 30 Hrs	
1. To Study Construction, Working and Performing Operations on a Lathe, Drilling, Grinding & Shaping Machine	
2. To study tool wear and tool life measurements for machinability	
3. Introduction of Computer Numerical Control Machines and working of few Models on CNC machine.	
4. Calibration of Micrometer, Vernier caliper, Thermocouple, Linear Variable Differential Transformer (LVDT), Load Cell To calibrate and measure the given component by using Micrometer, Vernier caliper, Thermocouple, Linear Variable Differential Transformer (LVDT), Load Cell	
5. Measurements using Optical Profile Projector, Toolmaker’s Microscope To measure the screw thread parameters of a given specimen using Optical Profile projector & Tool Maker’s Microscope	
6. Measurements of angle using Sine bar & universal bevel protractor To determine the unknown angle of the given specimen using sine bar with the help of slip gauge & universal bevel protractor	
7. Measurements of Screw thread parameters using two wire or three-wire methods - To find the effective diameter of a given screw thread by two or three wire method.	
8. Measurements of gear tooth profile using gear tooth Vernier caliper - To Measure the tooth thickness of the given gear using Gear Tooth Vernier Caliper	
9. Study the mechanism and working of 3D Printing machine	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Analyse and apply machining principles to optimize machining processes for efficiency and quality.
2	Evaluate and differentiate non-traditional machining processes suitable for advanced applications in machining.
3	Examine the operational mechanics of CNC machines and formulate part programs for 2D milling and drilling operations.
4	Apply measurement standards and system, Comparators and Slip gauges to calculate related errors during measurements.
5	Calculate tolerance, limits of size, fits, gauges and the various design concepts in gauging

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
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CO2	3	2	2	3	2	1	-	-	-	-	2	2	-
CO3	2	2	3	2	1	2	-	-	-	-	2	3	-
CO4	3	3	3	3	2	1	-	-	2	-	2	3	-
CO5	3	2	3	2	3	1	-	3	2	-	1	2	2

TEXT BOOKS:

1. P.N. Rao (2018) "Manufacturing Technology – Metal Cutting and Machine Tools," Volume-II,4 Edition, Tata McGraw Hill Publishing Company Ltd., New Delhi.
2. R.K. Jain (2009), Engineering Metrology, Khanna Publishers, New Delhi.

REFERENCES:

1. M. P. Groover (2019), "Fundamentals of Modern manufacturing" -materials, processes and systems Third Edition, Wiley publications, 7th Edition.
2. Kaushik Kumar, Chikesh Ranjan and Paulo Davim (2020) CNC Programming for Machining, Springer International Publishing.
3. Ernest O. Doebelin (2019), Measurement Systems: Application and Design, SIE Publications
4. Beckwith Marangoni and Lienhard (2006), Mechanical Measurements, Pearson Education, 6th Edition

E-Resources:

Activity Based Learning (Suggested Activities in Class)

1. Real world problem solving and puzzles using group discussion. E.g., Fake coin identification, Cabbage puzzle, Konigsberg bridge puzzle etc.,
2. Demonstration of solution to a problem through programming.

THERMODYNAMICS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Course Code	:	23ME2305	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. **Introduce** basic concepts related to thermodynamic system
2. **Understand** Zeroth law of thermodynamics as basis for temperature measurement. · Define first law of thermodynamics as applied to a closed and open systems
3. **Explain** working of heat engine and refrigeration cycles and to define second law of thermodynamics: Kelvin Planck and Clausius Statement.
4. **Understand** the property entropy through Clausius inequality
5. **Understand** behaviour of ideal and real gases through equation of state and compressibility factor.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

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- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	08 Hours

INTRODUCTION:

Basic Concepts of Thermodynamics: Introduction- Basic Concepts, Thermodynamic Equilibrium, Thermodynamic properties, Thermodynamic state, state point, path and process, quasi-static process, cyclic and non-cyclic processes, Energy and its forms, Work and heat (sign convention), Zeroth Law of Thermodynamics: Zeroth law of thermodynamics statement, Concept of Temperature and its' measurement. ***(Text Book-1: Chapter 1: 1.1 to 2.11)***

UNIT – II	08 Hours
First law of thermodynamics: Application to closed and open system, Joules experiments, equivalence of heat and work, Internal energy and enthalpy, energy as a property, specific heat at constant pressure and volume, PMM1, steady state, steady flow energy equation (SFEE), extension of first law to control volume, Limitations of first law of thermodynamics, Extension of SFEE to Various devices like-nozzle, turbine , pump/compressor, heat exchanger***(Text Book-1: Chapter 4: 4.1 to 5.4)***	

UNIT – III	06 Hours
Second Law of Thermodynamics: Thermal reservoirs, , devices converting work to heat in a thermodynamic cycle, heat engine, Efficiency reversed heat engine, heat pump, Refrigerator, Coefficient of Performance, Kelvin-Planck and Clausius statement of second law of thermodynamics, Equivalence of the two statements, reversible and irreversible processes, factors that make a process irreversible, Carnot cycle and Carnot engine, Carnot theorem and its corollaries. ***(Text Book-1: Chapter 6: 6.1 to 6.18)***	

UNIT – IV	08 Hours
Entropy: Classius Inequality: - Statement, proof, application to a reversible cycle, Entropy: Definition, a property, principle of increase of entropy, entropy as a quantitative test for irreversibility, Tds equation, calculation of entropy using TdS relations, entropy as a coordinate, Exergy(Available) and unavailable energy, Second law efficiency. ***(Text Book-1: Chapter 7: 7.1 to 7.18)***	

UNIT – V	09 Hours
Pure substance: Phase change process in a pure substance, Definition of triple, ice, steam and critical points, Property diagrams of pure substance, p-v, p-T, p-h, T-v, T-s diagrams, dryness fraction, use of steam tables. ***(Text Book-1: Chapter 9: 9.1 to 9.8)*** **Ideal and Real Gases** Gas laws- Boyle's Law, Charles Law, Gay-Lussac Law, Avogadro's law, equation of state - Vander Waals, Redlich-Kwong, Peng- Robinson etc. compressibility factor. ***(Text Book-1: Chapter 10: 10.1 to 10.19)***	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply laws of thermodynamics in temperature measurement and also calculate work and heat interaction of system with the environment
2	Analyse closed and open system performance using second law of thermodynamics
3	Calculate entropy change of a system and surrounding by undergoing a thermodynamic process
4	Estimate the maximum work potential of energy source based on the laws laid down by thermodynamics
5	Calculate thermodynamic properties of a pure substance in a given state

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	3	1	-	-	-	-	-	-	-	2
CO2	3	3	3	3	1	-	-	-	-	-	-	-	3
CO3	3	3	3	3	1	2	-	-	-	-	-	-	2
CO4	3	3	3	3	1	-	-	-	-	-	-	-	2
CO5	3	3	3	3	1	-	-	-	-	-	-	-	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. P.Nag (2017), Basic & Applied Thermodynamics, 2nd Edition, Mc Graw Hill Education.
2. Van Wylen, G.J., and Sonnatag, R.E., (2002), Fundamentals of Classical Thermodynamics for Engineers, 6th Edition, Wiley.

REFERENCE BOOKS:

1. Yunus A Cengel and Michael A Boles (2017), Thermodynamics: An Engineering Approach, McGraw Hill Education.
2. Michael J. Moran, Howard N. Shapiro (2006), Fundamentals of Engineering Thermodynamics, John Wiley & Sons Ltd, Chichester.

E-Resources:

1. https://nptel.ac.in/courses/102106026
2. https://www.classcentral.com/course/edx-thermodynamics-of-materials-21137
3. https://www.askiitians.com/iit-jee-thermal-physics/introduction-to-thermodynamics/
4. https://www.coursera.org/learn/thermodynamics-intro

Activity Based Learning (Suggested Activities in Class)

1. Use of simulations and modelling software to explore complex thermodynamic systems and see how changes in variables affect the overall behaviour of the system. For example, students could use a simulation to explore how changes in pressure and temperature affect the behaviour of a gas.
2. Experiments can help students visualize and experience the concepts they are learning about in class. For example, students could conduct experiments to measure the specific heat capacity of different materials or to observe phase changes in different substances.

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COMPUTER AIDED MACHINE DRAWING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Course Code	:	23ME2306	**Credits**	:	03
Hours / Week	:	05 Hours	**Total Hours**	:	65 Hours
L–T–P–S	:	1–0–0–4			

Course Learning Objectives:

The objectives of the Course are to:

1. Provide overview of various CAD software
2. Learn basics of sketching features
3. Create 3D models using extrude, revolve, draft & other advanced options
4. Introduce assembly concepts
5. Create simple & complex mechanical assemblies
6. Create industrial standard drawings with appropriate views including sectional views

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

Lecture method means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.

Interactive Teaching: *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.

- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I CAD OVERVIEW	**05 Hours**

CAD OVERVIEW:

Preferences-Settings, User Interface- Familiarize the User Interface by creating a simple design Familiarize The User Interface of Fusion 360 (Toolbar, Marking Menu, Browser, And Time Line Controls, Change of Workspace) Familiarize the User Interface of FUSION 360 (Navigations and data panel interface, Design Units and Origin, Quick Shape Creation) Use of toolbar, marking menu, browser and time line controls, change of workspace, Navigations and data panel interface, Design Units and Origin, Quick Shape Creation.

(Text Book-1: Chapter 1)

UNIT – II SKETCHING WORKSPACE	**10 Hours**

SKETCHING WORKSPACE:

Sketching Workspace: Creating a sketching geometry - Introduction to the Sketching Workflow Sketch Entities, ***(Text Book-1: Chapter 2)*** Dimensioning, Sketch Constraints. ***(Text Book-1: Chapter 3)*** Additional Sketching Tools- Additional Entity Types, Editing Tools, Additional Dimension Tools, Moving and Copying, Rectangular and circular Patterns. Sketched Secondary Features using existing geometry. Pick and Place Features- Fillets, Chamfers, Holes, Editing Pick and Place Features. Construction of planes, axis and points, creating a sketch using Equation and Parameters. ***(Text Book-1: Chapter 4)***	
UNIT – III SOLID MODELLING	**15 Hours**
SOLID MODELLING Introduction-Solid Modelling Basic Part modelling features- Extrude and revolve. Additional Features and Operations- Draft, Shell, Rib, Split Face, Scale, Thread, Press Pull. Direct Modelling Development of multi section solids and sweep. Feature Duplication – mirroring and patterning. ***(Text Book-1: Chapter 5, 6 & 7)*** Design and Display Manipulation- Reordering, inserting, suppressing Features, Measure and Section Analysis, Develop the part models and prepare the drafting. List out the operations involved to prepare the components. ***(Text Book-1: Chapter 8, 9 & 10))***	
UNIT – IV ASSEMBLY	**15 Hours**
ASSEMBLY Distributed Design- Assembly Design Methods, Joint Origins and Assigning Joints. Component Design Tools- Rigid Groups, Interference Detection Multi-Body Design- Multi- Body Design Tools, Components, As-Built Joints ***(Text Book-1: Chapter 11& 12)*** Drawing Basics-Creating a New Drawing, Additional Drawing Views, Exploded Views, Manipulating Drawings. Detailing Drawings- Dimensions, Parts List and Balloons, Annotation and Dimension Settings, Drawing Output. Data exchange standards – IGES, STP, STL, STEP etc ***(Text Book-1: Chapter 14))***	
UNIT – V MACHINE ASSEMBLY	**20 Hours**
MACHINE ASSEMBLY Develop the assembly drawing from the given detailed drawing (Swivel bearing) showing conventional representations with geometrical and dimensional constraints. Prepare the bill of materials for the given assembly ***(Text Book-2: Chapter 18: 18.5.8)*** Develop the assembly drawing from the given detailed drawing (steam engine connecting rod end) showing conventional representations with geometrical and dimensional constraints. Prepare the bill of materials for the given assembly ***(Text Book-2: Chapter 19: 19.2)*** Develop the assembly drawing from the given detailed drawing (Pressure relief valve) showing conventional representations with geometrical and dimensional constraints. Prepare the bill of materials for the given assembly ***(Text Book-2: Chapter 18: 18.4.8)*** Develop the assembly drawing from the given detailed drawing (Machine vice) showing conventional representations with geometrical and dimensional constraints. Prepare the bill of materials for the given assembly ***(Text Book-2: Chapter 18: 18.3.9)***	

Develop the assembly drawing from the given detailed drawing (Tailstock) showing conventional representations with geometrical and dimensional constraints. Prepare the bill of materials for the given assembly ***(Text Book-2: Chapter 18: 18.3.5)*** Develop the assembly drawing from the given detailed drawing (Piston of a petrol engine) showing conventional representations with geometrical and dimensional constraints. Prepare the bill of materials for the given assembly ***(Text Book-2: Chapter 18: 18.2.6)*** Develop the assembly drawing from the given detailed drawing (Air valve) showing conventional representations with geometrical and dimensional constraints. Prepare the bill of materials for the given assembly ***(Text Book-2: Chapter 18: 18.2.10)*** Develop the assembly drawing from the given detailed drawing (Fuel Injector) showing conventional representations with geometrical and dimensional constraints. Prepare the bill of materials for the given assembly ***(Text Book-2: Chapter 18: 18.2.11)*** Develop the assembly drawing from the given detailed drawing (Speed reducer) showing conventional representations with geometrical and dimensional constraints. Prepare the bill of materials for the given assembly ***(Text Book-2: Chapter 18: 18.5.15)*** Develop the assembly drawing from the given detailed drawing (Drill jig) showing conventional representations with geometrical and dimensional constraints. Prepare the bill of materials for the given assembly ***(Text Book-2: Chapter 18: 18.3.11)***

Course Outcome	Description
At the end of the course the student will be able to:	
1	Evaluate the functionality of different tools and features within a CAD tool for machine assembly requirements.
2	Employ sketching tools and features in a CAD tool to create precise and complex 2D sketches, considering appropriate sketch entities, dimensions, and constraints.
3	Utilize design constraints and parameters in a CAD tool to develop parametric 3D models, allowing for modification and adaptation of empirical relations.
4	Assess machine assembly models in a CAD tool, to identify any potential interferences, clashes, or design issues.
5	Generate precise and professional manufacturing drawings with appropriate dimensions, annotations, and GD&T symbols using CAD tools.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	2	2	-	2	-	-	-	-	-	1	3	-
CO2	3	1	1	-	3	-	-	2	2	-	1	3	-
CO3	3	2	1	-	3	-	-	2	2	-	1	3	1
CO4	3	2	1	-	3	-	-	3	3	-	2	3	1
CO5	2	1	1	-	3	-	-	1	3	-	2	3	1

Textbooks:

1. Willis, J., & Dogra, S. (2018). *Autodesk Fusion 360: A Power Guide for Beginners and Intermediate Users*. Createspace Independent Publishing Platform.
2. Narayana, K. L., Kanniah, P., & Venkata Reddy, K. (2016). *Machine Drawing* (5th ed.). New Age International Publishers.

Reference Books:

1. Gopalakrishna, K. R. (2017). *Machine Drawing in First Angle Projection*. Subhas Publication.
2. Bhat, N. D., & Panchal, V. M. (2016). *Machine Drawing*. Charotar Publishing House.

E-BOOKS / ONLINE RESOURCES/VIRTUAL LABS:

1. https://www.gutenberg.org/ebooks/39033

MOOC:

1. https://www.coursera.org/learn/fusion-360-integrated-cad-cam-cae

Activity Based Learning (Suggested Activities in Class)

1. Activity which makes students to apply the machine drawing concepts learned in the course during the drafting of 3D machine parts and its assembly using CAD tool, will be discussed in class.
2. Activity that makes the students for the development of skill set in the 3D modelling tool (Fusion 360).
3. Activity provides space to students giving responsibility for their own learning to make them into independent thinkers.
4. Activity that makes the students to have critical thinking, developing an expert mind set in Geometric dimensioning and tolerances, problem-solving and teamwork.

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Skill Enhancement Course-I
Autodesk Innovation Lab

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – III

Course Code	:	23ME2309	**Credits**	:	02
Hours / Week	:	04 Hours	**Total Hours**	:	52 Hours
L–T–P–S	:	0–0–4–0			

Course Description:

This course offers an in-depth exploration of Autodesk Inventor, focusing on mastering the creation and editing of 2D sketches and 3D models, designing and modifying complex parts and assemblies, constructing detailed surface models, and generating professional engineering drawings and documentation.

Course Learning Objectives:

This Course will enable students to:

1. Demonstrate proficiency in using Autodesk Inventor software to create and edit 2D sketches and 3D models.
2. Apply skills to design and modify complex parts and assemblies using Autodesk Inventor's part and assembly workbenches.
3. Develop the ability to construct and manage detailed surface models and execute advanced surface operations.
4. Generate professional engineering drawings and documentation, including standard views, dimensions, and annotations, using Autodesk Inventor's drafting tools.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I: Introduction to Autodesk Inventor and Basic Sketching	08 Hours

Week 1:
• **Introduction to Autodesk Inventor**
  ○ Overview of the software interface and workspace
  ○ Basic navigation and toolset introduction
• **2D Sketching Fundamentals**
  ○ Creating and editing 2D sketches
  ○ Basic sketch tools: lines, circles, arcs
  ○ Applying dimensions and constraints
Week 2:
• **Advanced Sketch Techniques**
  ○ Working with sketch constraints and relations
  ○ Modifying and optimizing sketches
Assignments/Project:
• Create and submit a set of 2D sketches incorporating various constraints and dimensions.	

UNIT – II: Fundamentals of 3D Modeling	**12 Hours**

Week 3:
• **Introduction to 3D Modeling**
  ○ Basic 3D features: extrude, revolve, sweep, loft
  ○ Creating and modifying 3D parts from sketches
Week 4:
• **Part Workbench Basics**
  ○ Overview of part design tools and features
  ○ Applying basic 3D operations
Week 5:
• **Advanced 3D Modeling Techniques**
  ○ Using advanced features: fillet, chamfer, pattern, mirror
  ○ Managing part parameters and history
Assignments/Project:
• Develop a 3D model from provided sketches, applying advanced modeling techniques.	

UNIT – III: Designing and Modifying Complex Parts and Assemblies	**12 Hours**

Week 6:
• **Designing Complex Parts**
  ○ Creating intricate parts using advanced features
  ○ Techniques for complex shape creation
Week 7:
• **Introduction to Assembly Workbench**
  ○ Creating assemblies from multiple parts
  ○ Applying assembly constraints: mate, flush, insert
Week 8:
• **Modifying and Troubleshooting Assemblies**
  ○ Techniques for modifying assemblies
  ○ Resolving common assembly issues and conflicts
Assignments/Project:
• Design and assemble a complex mechanical system using part and assembly	

workbenches.

UNIT – IV: Surface Modeling and Advanced Operations	12 Hours

Week 9:

- **Introduction to Surface Modeling**
  - Basics of surface modeling and its applications
  - Creating and managing surface bodies

Week 10:

- **Advanced Surface Operations**
  - Techniques for advanced surface creation: patch, trim, extend
  - Managing complex surfaces and blends

Week 11:

- **Surface Model Optimization**
  - Analyzing surface quality and making improvements
  - Repairing and refining surface models

Assignments/Project:

- Construct a detailed surface model incorporating advanced surface operations and optimization techniques.

UNIT – V: Engineering Drawings and Documentation	08 Hours

Week 12:

- **Creating Engineering Drawings**
  - Using the drafting workbench to generate 2D drawings from 3D models
  - Adding standard views, dimensions, and annotations
- **Documentation and Presentation**
  - Preparing and organizing engineering documentation
  - Best practices for professional presentation

Week 13:

- **Final Project Preparation**
  - Integrating skills from previous units to complete a final project
  - Preparing and presenting complete engineering drawings and documentation

Assignments/Project:

- Generate a comprehensive set of engineering drawings for a complex assembly, including all necessary annotations and documentation.

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply advanced sketch techniques to create and optimize a set of 2D sketches, demonstrating proficiency in using basic tools, constraints, and dimensions.
2	Develop and modify a 3D model from sketches by applying basic and advanced features, including extrude, fillet, and chamfer, and managing part parameters and history.
3	Construct and enhance a detailed surface model by applying advanced techniques such as patch, trim, and extend, and analyzing and optimizing surface quality for

	improved performance.
4	Apply advanced surface modeling techniques to construct and refine a detailed surface model, analyzing and improving surface quality through techniques such as patch, trim, and extend.
5	Generate and organize a comprehensive set of engineering drawings for a complex assembly by applying drafting techniques, adding standard views, dimensions, and annotations, and preparing the documentation for professional presentation.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	1	2	-	3	-	-	2	2	1	1	3	3
CO2	2	2	2	1	3	-	-	2	2	-	3	2	2
CO3	3	2	3	1	3	-	-	2	1	-	3	3	3
CO4	2	2	2	1	3	-	-	2	2	-	3	3	3
CO5	3	2	3	1	3	-	-	2	2	-	3	3	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Text Books:
1. Autodesk Inventor 2024: A Tutorial Introduction by L. Scott Hansen (Author).
2. Autodesk Inventor Exercises: 200 Practice Drawings for Autodesk Inventor and Other Feature-Based Modeling Software,

Reference Books:
1. Autodesk Inventor 2023: A Power Guide for Beginners and Intermediate Users Users 4th ed. Edition, by CADArtifex, John Willis, Sandeep Dogra.

Assessment Methods:
- **Assignments and Projects:** Regular assignments and hands-on projects based on weekly topics.
- **Mid-Term Exam:** Assessment covering Units 1 through 3.
- **Final Project:** A comprehensive project that demonstrates proficiency in all course objectives, including engineering drawings and documentation.

Recommended Textbooks and Resources:
- Autodesk Inventor official documentation and tutorials
- Recommended textbooks on CAD modeling and engineering design
- Online resources and video tutorials for additional practice

Course Schedule:
- **Weeks 1-2:** Unit 1
- **Weeks 3-5:** Unit 2
- **Weeks 6-8:** Unit 3
- **Weeks 9-11:** Unit 4

- **Weeks 12-13:** Unit 5

This syllabus provides a structured path to mastering Autodesk Inventor, ensuring that students achieve the learning objectives through both theoretical instruction and practical application.

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PROBABILITY AND STATISTICS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Course Code	:	23ME2401	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

<u>Course Learning Objectives:</u>

This Course will enable students to:

1. Apply statistical principles and probability concepts to solve complex problems in real-world scenarios involving uncertainty and randomness.
2. Evaluate and select appropriate probability distributions and statistical techniques to analyze and interpret data accurately in various applications.
3. Justify the use of estimation methods and hypothesis testing techniques for drawing meaningful inferences about population parameters.
4. Analyze and interpret sample test results for different statistical relationships, such as means, variances, correlation coefficients, regression coefficients, goodness of fit, and independence, to make informed decisions.
5. Identify sample tests using appropriate statistical procedures to investigate the significance of observed data and communicate findings effectively.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I: Probability	**09 Hours**
Definitions of Probability, Addition Theorem, Conditional Probability, Multiplication Theorem, Bayes' Theorem of Probability	
UNIT – II: Random Variables and their Properties and Probability	**09 Hours**

Distributions	
Discrete Random Variable, Continuous Random Variable, Joint Probability Distributions Their Properties, Probability Distributions: Discrete Distributions: Binomial, Poisson Distributions and their Properties; Continuous Distributions: Exponential, Normal, Distributions and their Properties.	
UNIT – III: Estimation and testing of hypothesis	**06 Hours**
Sample, Populations, Statistic, Parameter, Sampling Distribution, Standard Error, Un-Biasedness, Efficiency, Maximum Likelihood Estimator, Notion & Interval Estimation.	
UNIT – IV: Sample Tests-1	**07 Hours**
Large Sample Tests Based on Normal Distribution, Small Sample Tests: Testing Equality of Means, Testing Equality of Variances, Test of Correlation Coefficient	
UNIT – V: Sample Tests-2	**08 Hours**
Test for Regression Coefficient; Coefficient of Association, 2 – Test for Goodness of Fit, Test for Independence.	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Apply the principles of probability to solve complex problems in various real-world scenarios.
2	Solve and compare different probability distributions, including discrete and continuous random variables, in order to make informed decisions and predictions.
3	Apply statistical estimation techniques, such as maximum likelihood estimation and interval estimation, to draw meaningful inferences about population parameters from sample data.
4	Examine hypothesis testing methods, including large and small sample tests, to assess the significance of observed data and draw valid conclusions.
5	Analyze statistical relationships and perform sample tests to assess the Equality of means in different populations, Correlation coefficients between variables to determine the strength and direction of the relationship. Independence of variables using appropriate statistical tests to assess the absence of any relationship.

Table: Mapping Levels of COs to POs / PSOs

COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	2	-	2	-	-	1	-	-	-	-	-
CO2	3	2	2	-	2	-	-	1	-	-	-	-	-
CO3	3	2	2	-	-	-	-	1	-	-	-	-	-
CO4	3	2	2	-	2	-	-	1	-	-	-	-	-
CO5	3	2	2	-	2	-	-	1	-	-	-	-	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbook:

1. Walpole, R. E., Myers, R. H., Myers, S. L., & Ye, K. (n.d.). *Probability & Statistics for Engineers and Scientists*. Pearson Education.

Reference Books:

1. Veerarajan, T. (n.d.). *Probability, Statistics and Random Processes*. Tata McGraw-Hill.
2. Trivedi, K. S. (1999). *Probability & Statistics with Reliability, Queuing and Computer Applications*. Prentice Hall of India.

E-Resources:

1. https://nptel.ac.in/courses/106104233
2. https://nptel.ac.in/courses/117103067
3. https://nptel.ac.in/courses/103106120
4. https://www.coursera.org/learn/probability-intro#syllabus
5. https://nptel.ac.in/courses/111104073

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APPLIED THERMAL SYSTEMS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Course Code	:	23ME2402	**Credits**	:	04
Hours / Week	:	05 Hours	**Total Hours**	:	45+30 Hours
L–T–P–S	:	3–0–2–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand Vapour power cycles and calculation of heat, work interactions and thermal efficiency
2. Explain the working of a single stage and multistage compressor and to calculate work done, volumetric-isothermal-polytrophic efficiencies
3. Understand refrigeration cycle and calculation of COP and to study different types of refrigerants and to appreciate the use of eco-friendly refrigerants
4. Study combustion thermodynamics of fuels
5. Carry out tests to investigate the performance of internal combustion engines
6. Describe and illustrate the idea of Backtracking and Branch and Bound algorithm design techniques to solve a given problem.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
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- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	08 Hours
Gas Power Cycles Review of thermodynamics laws, Carnot, Otto, Diesel and Dual Cycles; simple Gas turbine cycle (Brayton cycle) and Modifications; Multistage compression with intercooling, Regeneration, reheat cycles practical gas turbine, cycles; Jet Propulsion cycles ***(Text Book-2: Chapter 13.1: 13.22)***,	
UNIT – II	**08 Hours**
Vapour Power Cycles and Combined cycle power plants Components of steam power plant, Carnot vapour power cycles, limitation of Carnot cycle, Simple Rankine cycle; Effect of pressure and Temperature on performance of Rankine Cycle, Comparison of Carnot and Rankine cycles. Effects of pressure and temperature on Rankine cycle performance. Actual vapour power cycles. Ideal and practical regenerative Rankine cycles, feed water heaters. Reheat Rankine cycle, Supercritical Rankine cycle, combined gas and vapour cycle power plants. Numerical ***(Text Book-2: Chapter 12:12.1, 12.14)***	
UNIT – III	**06 Hours**
Reciprocating Compressors Classification; work done in a single stage compressor; efficiency; p-v diagram for an actual compressor and diagram factor; multistage compressor; Multistage compressor with intercooler, Performance parameters for reciprocating compressors ***(Text Book-2: Chapter 17:17.1, 17.06)***	
UNIT – IV	**10 Hours**
Refrigeration and Air conditioning Vapour compression refrigeration system; description, analysis, refrigerating effect. Capacity, power required, units of refrigeration, COP, Refrigerants and their desirable properties, alternate Refrigerants. Vapour absorption refrigeration system. Psychometric: Nomenclature, Definition, use of Psychometric chart, Introduction to air-conditioning, different types of air-conditioning systems***(Text Book-2: Chapter 14:14.1, 14.12)***	
UNIT – V	**08 Hours**
Combustion Thermodynamics Theoretical (Stoichiometric) air for combustion of fuels. Excess air, mass balance, Exhaust gas analysis, A/F ratio. Energy balance for a chemical reaction, enthalpy of formation, enthalpy and internal energy of combustion. Combustion efficiency. Dissociation and equilibrium, emissions. ***(Text Book-2: Chapter 19:19.1, 19.10)***	

Sl. No	List of Laboratory/Practical Experiments activities to be conducted (if any) Total 30 Hrs
1	Determination of Flash point and Fire point of lubricating oil using Abel, Pensky and Marten's (closed) / Cleveland's (Open Cup) Apparatus.
2	Determination of Calorific value of solid, liquid and gaseous fuels.
3	Determination of Viscosity of lubricating oil using Redwoods, Saybolt and Torsion Viscometers.
4	Valve Timing/port opening diagram of an I.C. engine (4 stroke/2 stroke).
5	Performance Tests on I.C. Engines, Calculations of IP, BP, Thermal Efficiencies, Volumetric efficiency, Mechanical efficiency, SFC, FP, A-F Ratio, heat balance sheet
6	Determination of temperature distribution, fin efficiency in natural / forced Convection

Course Outcome	Description
At the end of the course the student will be able to:	
1	Calculate work obtained, mean effective pressure and thermal efficiency for Otto, Diesel, Dual and Bryton cycles, Thermal efficiency of Basic, modified, reheat and regenerative Rankine cycles
2	Calculate the work done and efficiency for single stage and multistage compressor
3	Analyze different refrigeration and air-conditioning cycles and combustion thermodynamics of fuels
4	Estimate the properties of fuels and lubricants like flash and fire point, viscosity and calorific value.
5	Calculate I C engine performance at different operating conditions and also to carry out heat balance

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	3	3	-	-	-	-	-	-	-	2
CO2	3	3	3	3	2	-	-	-	-	-	-	-	2
CO3	3	3	3	3	2	-	-	-	-	-	-	-	2
CO4	3	3	2	2	2	2	-	-	-	-	-	-	1
CO5	3	3	3	3	3	3	-	-	-	-	-	2	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. Kadambi, T. R., Seetaraman, K. B., & Kumar, S. (2019). *Applications of Thermodynamics*. Wiley India Private Ltd.
2. Nag, P. K. (2017). *Basics and Applied Thermodynamics* (2nd ed.). Tata McGraw-Hill.

Reference Books:

1. Cengel, Y. A., & Boles, M. A. (2017). *Thermodynamics: An Engineering Approach*. McGraw Hill Education.
2. Moran, M. J., & Shapiro, H. N. (2006). *Fundamentals of Engineering Thermodynamics*. John Wiley & Sons Ltd.

E-Resources:

1. https://nptel.ac.in/courses/112103307
2. https://archive.nptel.ac.in/courses/112/106/112106314/
3. http://gateandupscexammaterials.yolasite.com/resources/standard_books/Applied%20Thermodynamics%20by%20Onkar%20Singh.0001.
4. https://onlinecourses.nptel.ac.in/noc22_me113/preview

Activity Based Learning (Suggested Activities in Class)

1. students to conduct a thermodynamic analysis of a refrigerator using the principles of thermodynamics they have learned. This will help them understand how refrigerators work and how energy is transferred in a refrigeration cycle.

2. students to conduct experiments on the thermodynamic properties of materials, such as thermal conductivity and specific heat. This activity will help students understand how the properties of materials affect their thermodynamic behaviour.

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KINEMATICS AND DYNAMICS OF MACHINES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Course Code	:	23ME2403	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Impart knowledge on the kinematics and dynamics of planar mechanisms
2. Analyze the bodies which is in motion using the basics of kinetics and kinematics
3. Determine the balancing of masses of rotating and reciprocating machine elements
4. Understand the principles of cams and followers
5. Distinguish the performance of different governors by characterize effort, power and sensitiveness
6. Understand the gyroscopic principle and verifying its effect by changing the torque.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I BASICS OF MECHANISMS	**07 Hours**

BASICS OF MECHANISMS

Definitions Link or element, kinematic pairs, chain, Mechanism and Structure, Degrees of freedom, Grubler's criterion.

(Text Book-1: Chapter 1: 1.1, 1.2, 1.4, 1.5, .6, 1.7, 1.8, 1.9, 1.10, 1.11)

Inversions of various mechanism. Quick return motion Mechanisms.

(Text Book-1: Chapter 1: 1.12, 1.13, 1.16, 1.17, 1.18)

Straight line motion mechanisms. Intermittent Motion mechanisms. Toggle mechanism, Pantograph, Steering gears mechanism. Universal Hook's Joint.

(Text Book-1: Chapter 6: 6.1, 6.2, 6.4, 6.5, 6.7, 6.8,6.9)

UNIT – II KINEMATIC ANALYSIS	**07 Hours**

KINEMATIC ANALYSIS
Velocity and acceleration analysis of Four Bar mechanism, slider crank mechanism.
(Text Book-1: Chapter 2 & 3: 2.1, 2.5, 2.6, 2.7, 2.8, 2.93.1, 3.2, 3.4)
Relative velocity and acceleration of particles in a common link and coincident Particles on separate links- Coriolis component of acceleration.
(Text Book-1: Chapter 2 & 3: 2.10, 3.5, 3.6)
Velocity Analysis by Instantaneous Center Method. Klein's Construction: Analysis of velocity and acceleration of single slider crank mechanism.
(Text Book-1: Chapter 2 & 3: 2.12, 2.13, 2.14, 3.8)

UNIT – III STATIC AND DYNAMIC FORCE ANALYSIS	08 Hours

STATIC AND DYNAMIC FORCE ANALYSIS
Introduction, Static equilibrium. Equilibrium of two and three force members, members with two forces and torque, free body diagrams. Principle of virtual work, static force analysis of various mechanisms with and without friction.
(Text Book-1: Chapter 12 : 12.1, 12.2, 12.3, 12.4, 12.5, 12.6, 12.7, 12.8, 12.9)
Dynamic Force Analysis: D'Alembert's principle, inertia force and torque. Dynamic force analysis of four-bar and slider crank mechanism.
(Text Book-1: Chapter 13 : 13.1, 13.2, 13.3, 13.4, 13.5, 13.7, 13.10)

UNIT – IV BALANCING OF ROTATING AND RECIPROCATING MASSES	07 Hours

BALANCING OF ROTATING AND RECIPROCATING MASSES
Static and dynamic balancing. Balancing of single and several rotating mass.
(Text Book-1: Chapter 14 : 14.1, 14.2, 14.3, 14.4)
Balancing of single cylinder engine: multi cylinder-inline engine (primary & secondary forces), V-type engine. Balancing of locomotives
(Text Book-1: Chapter 14 : 14.6, 14.7, 14.8, 14.9, 14.10, 14.11)

UNIT – V CAMS, GOVERNORS, AND GYROSCOPE	10 Hours

CAMS, GOVERNORS, AND GYROSCOPE
Types of cams and followers. Development of cam profile for various types of followers and its different motion.
(Text Book-1: Chapter 7 : 7.1, 7.2, 7.3, 7.5, 7.8, 7.9)
Governors: Types of governors; governor characteristics, force analysis of centrifugal governors.
(Text Book-1: Chapter 16 : 16.1, 16.2, 16.3, 16.4, 6.5, 16.11, 16.12, 16.13, 16.14, 16.15, 16.16, 16.17)
Gyroscope: Vector representation of angular motion. Gyroscopic couple, effect of gyroscopic couple on ship, plane disc, aeroplane.
(Text Book-1: Chapter 17 : 17.1, 17.2, 17.3, 17.4, 17.5, 17.6, 17.7)

Course Outcome	Description
At the end of the course the student will be able to:	
1	Analyse and interpret the behaviour of kinematic mechanisms to understand their motion characteristics
2	Apply kinematic principles and concepts to analyse the motion characteristics of mechanical systems and mechanisms.
3	Evaluate the equilibrium of rigid bodies Courseed to static and dynamic forces using appropriate
4	Determine the magnitude and location of balancing masses by utilizing appropriate balancing procedures
5	Analyse cam profiles for various followers, evaluate governor characteristics and

	perform force analysis of centrifugal governors, and apply gyroscopic principles to understand the effects on ships, planes, and discs.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	1	-	1	-	-	1	-	-	-	2	-
CO2	3	3	2	2	1	1	-	2	-	-	-	3	2
CO3	3	3	2	2	1	1	-	2	-	-	-	3	2
CO4	3	2	2	-	-	1	-	1	-	-	-	3	2
CO5	3	2	1	-	-	-	-	1	-	-	-	2	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. Rattan, S. S. (2014). *Theory of Machines*. Tata McGraw-Hill Publishing Company Ltd.
2. Uicker, J. J., Pennock, G. R., & Shigley, J. E. (2010). *Theory of Machines & Mechanisms* (4th ed.). Oxford University Press.

Reference Books:

1. Bevan, T. (2005). *Theory of Machines* (3rd ed.). CBS Publication.
2. Ghosh, A., & Mallik, A. K. (1976). *Theory of Mechanisms and Machines* (3rd ed.). Affiliated East-West Press.

E-Books / Online Resources/VIRTUAL LABS:

1. https://mm-nitk.vlabs.ac.in/

MOOC:

1. https://nptel.ac.in/courses/112105268
2. https://archive.nptel.ac.in/courses/112/104/112104114/#

Activity Based Learning (Suggested Activities in Class)

1. Activity which makes students to apply the concepts learned in the course to the development of mechanism based on the real time applications will be discussed in class.
2. Activity that makes the students for the development of skill set in analysis of mechanisms.
3. Activity provides space to students giving responsibility for their own learning to make them into independent thinkers.
4. Activity that makes the students to have critical thinking, developing an expert mind set, problem-solving and teamwork.

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MECHANICS OF SOLIDS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Course Code	:	23ME2404	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Explain about the analysis of stresses and strains in straight, Stepped and tapered sections, Composite sections under axial, shear & thermal loading conditions.
2. Describe the evaluation of compound stresses and strains in a structural member using analytical & Mohr's circle method. And
3. Determine the circumferential and longitudinal stresses in thin and thick cylindrical pressure vessels.
4. Describe about the construction of shear force and bending moment diagrams for cantilever, simply supported and overhanging beams Courseed to concentrated loads, uniformly distributed loads, moments and uniformly varying loads.
5. Calculate the shear stress due to torsion in tapered shaft, Shafts in series and Parallel, Thin Tubular and Thin-walled sections. And
6. Explain how to use Euler's Theory of Columns to calculate the buckling load of the columns with pinned ends, both ends are fixed, one end fixed & other is free and one end fixed & other is hinged.
7. Describe about computation of strain energy due to axial, shear, bending & torsional stresses. Clarify how to use Theories of Failure to determine the factor of safety when it is Courseed to combined stresses.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.

- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I Analysis of Stress and Strain	**08 Hours**

INTRODUCTION:
Introduction, Properties of materials, Stress, Strain and Hooke's law, Stress strain diagram for brittle and ductile materials, True stress and strain, Shear stress and strain, Lateral strain and Poisson's ratio, Elastic constants and relations between them.
Calculation of stresses in straight, Stepped and tapered sections, Composite sections, Stresses due to temperature change. ***(Text Book-1: Chapter 2: 2.3 to 2.11)***

UNIT – II Compound Stresses and Cylinders	**08 Hours**

Compound Stresses: Principal stresses and maximum shear stress, Planes of Principalstress and Maximum Shear stress, Normal stress on the planes of maximum shear stress, Mohr's circle for plane stress conditions. ***(Text Book-3: Chapter 3: 3.4, 3.5)***
Cylinders: Thin cylinder: Hoop's stress, maximum shear stress, circumferential and longitudinal strains, thin spherical Shell, thin cylinder with spherical ends. Thick cylinders: Lame's theory. ***(Text Book-2: Chapter 17: 17.4,17.5,17.10)***

UNIT – III Shear Forces and Bending Moments	**06 Hours**

Shear Forces and Bending Moments: Type of beams, Loads and reactions, Relationship between loads, Shear force and bending moments of cantilever, simply supported and overhanging beams Courseed to concentrated loads and uniformly distributed constant / varying loads. . ***(Text Book-2: Chapter 6: 6.3 to 6.18)***
Stress in Beams: Bending Theory**,** Bending and shear stress distribution in rectangular,I and T section beams. ***(Text Book-2: Chapter 7: 7.2 to 7.4)***

UNIT – IV Torsion and Columns	**09 Hours**

Torsion: Circular shafts, Power Transmission, Torsion of tapered shaft, Shafts inseries and Parallel, Thin Tubular and Thin-walled sections. ***(Text Book-1: Chapter 3: 3.3, 3.13).***
Columns: Euler's theory, Equivalent Length, Limitations of Euler's Formula, Rankines Formula ***(Text Book-2: Chapter 19: 19.3 to 19.10).***

UNIT – V Strain Energy and Theories of Failure	**08 Hours**

Strain Energy: Strain energy due to axial, shear, bending, torsion and impact load, Castigliano's theorem and their applications. ***(Text Book-1: Chapter 11: 11.2 to 11.12***)
Theories of Failure: Introduction, maximum principal stress theory (Rankine's theory), Maximum shearing stress theory (Guest's and Tresca's theory), maximum principal strain theory (St. Venant's theory), Maximum Strain energy theory (Haigh's Theory) and Maximum Shear Strain Energy Theory (Mises' and Henkeys's Theory) ***(Text Book-2: Chapter 04: 4.1 to 4.4***)

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply fundamental concepts of stress, strain, and material properties to analyse and calculate stresses in various sections and composite materials, including the effects of temperature changes.
2	Analyse compound stresses in materials by determining principal stresses, maximum shear stresses, and normal stresses using Mohr's circle, and evaluate stresses and strains in thin and thick cylinders.
3	Evaluate shear forces and bending moments in various types of beams under different loading conditions and analyse stress distribution using bending theory for rectangular, I, and T section beams.
4	Apply torsion principles to analyse circular and tapered shafts, including power transmission and thin-walled sections, and assess column stability using Euler's and Rankine's formulas to determine critical loads and limitations
5	Analyse strain energy in materials Courseed to axial, shear, bending, torsion, and impact loads using Castigliano's theorem, and apply various theories of failure to predict material behaviour under complex stress conditions.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	2	-	-	-	-	-	-	-	1	2
CO2	3	2	2	2	-	-	-	-	-	-	-	1	2
CO3	2	2	2	2	-	-	-	-	-	-	-	2	1
CO4	2	2	3	3	-	-	-	-	-	-	-	1	1
CO5	3	2	3	3	-	-	-	-	-	-	-	2	2

Textbooks:
1. Beer, F. P., & Johnston, E. R. (2020). Mechanics of Materials (8th ed.). McGraw Hill.
2. Bhavikatti, S. S. (2017). Mechanics of Solids. New Age International Publications.

Reference Books:
1. Timoshenko, S. (2002). Strength of Materials (3rd ed.). CBS Publisher.
2. Ramamrutham, S. (2011). Strength of Materials. Dhanpat Rai Publishing Company.

E-Resources:
1. https://archive.nptel.ac.in/courses/105/105/105105108/
2. https://onlinecourses.nptel.ac.in/noc22_ce46/preview
3. https://www.youtube.com/watch?v=LIZ-PQbGZkA

Activity Based Learning (Suggested Activities in Class)
1. Real world problem solving and puzzles using group discussion.
2. Demonstration of solution to a problem through experiential learning.
3. Demonstrations using real objects, taking students on an educational tour.

HEAT TRANSFER

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Course Code	:	23ME2405	**Credits**	:	04
Hours / Week	:	05 Hours	**Total Hours**	:	45+30 Hours
L–T–P–S	:	3–0–2–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the basic phenomenon of heat transfer and its importance in engineering applications.
2. Enable the students to understand the different modes of heat transfer like conduction, convection and radiation.
3. Understand the mechanism of heat transfer under steady and transient conditions
4. Illustrate the applications of convective heat transfer including heat exchangers, boiling & condensation
5. Understand the different laws of radiation and applying for solving engineering problems

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	05 Hours

Modes of heat transfer: Basic laws governing conduction, Thermal conductivity. Conduction: Derivation of general three-dimensional conduction equation in Cartesian coordinate, discussion on 3-D conduction in cylindrical and spherical coordinate system. One dimensional conduction equation for plane, cylinder and spheres. Overall heat transfer coefficient, Thermal conductive resistance and numerical problems. Derivation for heat flow and temperature distribution in a plane for variable thermal conductivity case, critical thickness of insulation and numerical problems. ***(Text Book2: Chapter 1: 1.1, 1.6)***

UNIT – II	05 Hours
Heat transfer through rectangular fin, infinitely long fin, short fin with insulated tip and without insulated tips. FIN efficiency and effectiveness. Numerical problems. ***(Text Book 1: Chapter 3: 3.1, 3.8)*** **Transient Conduction**: Lumped parameter analysis, use of transient temperature charts (Heisler's charts) for transient conduction in slab, long cylinder and sphere, numerical problems ***(Text Book1: Chapter 4: 4.1, 4.7)***	
UNIT – III	**05 Hours**
Natural Convection: Introduction, laminar flow, momentum and energy equations for vertical flat plate, physical significance of Grashoff number, use of correlations for free convection in vertical, horizontal and inclined flat plates, vertical and horizontal cylinders and spheres, numerical problems. ***(Text Book1: Chapter 6: 6.1, 6.7)*** **Forced Convection**: Applications of dimensional analysis for forced convection. Physical significance of Reynolds, Prandtl, Nusselt and Stanton numbers. Use of various correlations for hydro dynamically and thermally developed flows inside a duct, use of correlations for flow over a flat plate, over a cylinder and sphere. Numerical problems. ***(Text Book1: Chapter 9: 9.1, 9.7)***	
UNIT – IV	**06 Hours**
Fundamental concepts of radiation, different laws governing radiation heat transfer, Stefan Boltzman law, Kirchoff's law, Planck's law, Wein's displacement law, Intensity of radiation and Lambert's cosine law, Radiation shape factor, Heat exchange by radiation between two black and diffuse grey surfaces, radiation shields, numerical problems. ***(Text Book1: Chapter 12: 12.1, 12.11)***	
UNIT – V	**05 Hours**
Heat exchangers: Classification and applications, overall heat transfer coefficient, heat exchanger analysis–Logarithmic mean temperature difference for parallel and counter flow heat exchanger, effectiveness–number of transfer units, method for parallel and counter flow heat exchanger, introduction to cross flow heat exchanger, Logarithmic mean temperature difference correction factor. Numerical problems. ***(Text Book1: Chapter 11: 11.1, 11.08)*** **Condensation and Boiling**: Boiling heat transfer, types of boiling, pool boiling curve and forced boiling phenomenon, condensation heat transfer, film wise and drop wise condensation. (no numerical problems). ***(Text Book1: Chapter 10: 10.1, 10.11)***	

Sl. No	**List of Laboratory/Practical Experiments activities to be conducted (if any) Total 30 Hrs**
1	Determination of thermal conductivity of metal rod.
2	Determination of thermal conductivity of composite wall.
3	Experiment on transient conduction heat transfer
4	Determination of heat transfer coefficient in natural convection.
5	Determination of heat transfer coefficient in forced convection.
6	Determination of temperature distribution, fin efficiency in natural / forced Convection
7	Determination of emissivity of a test surface.
8	Determination of the emissive power of black body using Stefan's Boltzmann's constant
9	Determination of effectiveness and logarithmic mean temperature difference in parallel flow and counter flow heat exchanger

Course Outcome	Description
At the end of the course the student will be able to:	
1	Compute temperature distribution and heat flow in a steady and unsteady-state 1-D heat conduction problems for various arrangements and also predict the performance parameters for fin
2	Evaluate the principles of natural and forced convection, the significance of key dimensionless numbers, and applicable correlations, to solve complex numerical problems in convention heat transfer
3	Apply fundamental principles and laws of radiation heat transfer to solve complex heat transfer problems
4	Analyse performance characteristics of heat exchangers using LMTD and Effectiveness NTU approaches
5	Evaluate and synthesize experimental data to determine thermal conductivity, heat transfer coefficient, temperature distribution, fin efficiency, emissivity, and also critically assess the effectiveness of heat exchangers and black body radiation characteristics.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	2	2	-	-	-	-	-	-	-	1	3
CO2	3	2	2	2	-	-	-	-	-	-	-	1	3
CO3	3	3	2	3	-	-	-	-	-	-	-	-	3
CO4	3	3	3	2	-	-	-	-	-	-	-	-	3
CO5	3	3	3	3	2	-	-	3	2	1	-	2	3

Textbooks:

1. Incropera, F. P., & DeWitt, D. P. (2011). *Fundamentals of Heat and Mass Transfer*. John Wiley & Sons.
2. Holman, J. P. (2009). *Heat Transfer*. Tata McGraw-Hill.

Reference Books:

1. Nag, P. K. (2011). *Heat and Mass Transfer*. Tata McGraw-Hill.
2. Özisik, M. N. (2002). *Heat Transfer: A Basic Approach*. McGraw-Hill.

E-Resources:

1. https://archive.nptel.ac.in/courses/103/105/103105140/
2. http://ecoursesonline.iasri.res.in/course/view.php?id=625
3. http://ecoursesonline.iasri.res.in/course/view.php?id=61
4. http://krunalkhiraiya.weebly.com/e-course-on-heat-transfer.html

Activity Based Learning (Suggested Activities in Class)

1. Conduct a thermal conductivity experiment: Provide students with materials such as different types of metals

2. Investigate the effects of insulation: Provide students with materials such as Styrofoam, cotton, and wool, and have them investigate the effects of insulation on heat transfer by measuring the rate of heat loss from a hot object that is wrapped in each material.

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MACHINE LEARNING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Course Code	:	23ME2406	**Credits**	:	02
Hours / Week	:	03 Hours	**Total Hours**	:	13+30 Hours
L–T–P–S	:	1–0–2–0			

Course Learning Objectives:

This Course will enable students to:

1. Realize Machine Learning techniques in supervised and unsupervised learning.
2. Comprehend the ideas of ML and problem-solving techniques.
3. Use of Python Programming for different applications
4. Demonstrate the representation of knowledge and reasoning
5. Recognize the importance of ML in Mechanical Engineering

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	08 Hours

Introduction to Python, Basics: Basic types, variables, Decision making and Loops, Strings, DataStructures: Lists, Tuples, Sets, and Dictionaries Regular Expression Operations, Modules.
Object oriented programming in python: Classes, Constructors, and Object Methods. ***(Text Book-1: Chapter 5: 5.1 to 5.3, Chapter 6: 6.3 to 6.4, Chapter 7: 7.2 to 7.3)***

UNIT – II	

NumPy - Overview, NumPy Array creation and basic operations, NumPy Universal functions, Selecting and retrieving Data, Data Slicing.
Pandas - Overview, Object Creation: Series Object, Data Frame Object, View Data, selecting data by Label and Position, Data Slicing, Setting Data, applying functions to data, Analysing Data for missing values.

Matplotlib - Overview, creating basic chart: Line Chart, Bar Charts and Pie Charts, Plotting from Pandas object, Saving a plot. ***(Text Book-1: Chapter 8: 8.4).***

UNIT – III	**06 Hours**
INTRODUCTION: Introduction to Supervised learning, Linear Regression Logistic Regression, Naive Bayes, Decision Tree, KNN, Random Forest, Support VectorMachine Introduction to Unsupervised learning, PCA, clustering approaches: K-means, Hierarchical clustering Natural Language Processing: Language models, n-grams, Vector space models, Bag of words. ***(Text Book-1: Chapter 1: 1.1 to 1.2)***	

UNIT – IV	**08 Hours**
Neural Network basics: History behind neural networks, Relationship between biological neuron and artificial neuron, Perceptron and working mechanism, Architecture of artificial neuralnetwork, Types of activation functions. ***(Text Book-1: Chapter 3: 3.1, 3.2)***	

UNIT – V	**08 Hours**
Machine learning application using python for mechanical engineering datasets: mechanical vibrations - heat transfer - fluid mechanics – manufacturing process. Smart Manufacturing, Smart Transportation and Autonomous Vehicles. Robotics, Quality control. ***(Text Book-1: Chapter 12: 12.2, 12.3***)	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Apply object-oriented programming concepts proficiently in Python, demonstrating expertise in Python programming fundamentals through practical application.
2	Analyze data using NumPy for array operations, Pandas for data manipulation, and Matplotlib for creating and visualizing basic charts.
3	Evaluate supervised and unsupervised learning algorithms, including linear regression, logistic regression, decision trees, KNN, random forest, SVM, PCA, K-means, and hierarchical clustering, and apply natural language processing techniques
4	Analyze foundational aspects of neural networks, encompassing their working mechanism and architecture of artificial neural networks.
5	Apply machine learning techniques using Python to analyse dataset of mechanical vibrations, heat transfer, fluid mechanics, and manufacturing processes, and develop solutions for smart manufacturing, transportation

Table: Mapping Levels of COs to POs / PSOs

COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	1	1	3	-	-	-	1	-	2	1	1
CO2	3	3	3	1	3	-	-	-	2	-	3	1	1
CO3	3	3	3	3	3	-	1	1	2	-	3	1	1
CO4	3	3	2	2	3	-	-	-	-	-	2	1	1
CO5	3	3	3	2	3	-	1	2	2	-	2	3	3

Textbooks:

1. Nagy, Z. (2018). *Artificial Intelligence and Machine Learning Fundamentals: Develop real-world applications powered by the latest AI advances*. Packt Publishing Ltd.
2. Raschka, S., & Mirjalili, V. (2017). *Python Machine Learning, Second Edition: Machine Learning and Deep Learning with Python, scikit-learn, and TensorFlow*. Packt Publishing Ltd.

Reference Books:

1. Poole, D. L., & Mackworth, A. K. (2010). *Artificial Intelligence: Foundations of Computational Agents*. Cambridge University Press.
2. Nilsson, N. J. (2009). *The Quest for Artificial Intelligence*. Cambridge University Press.

E-Resources:

1. https://nptel.ac.in/courses/106/101/106101060/
2. http://cse01-iiith.vlabs.ac.in/
3. http://openclassroom.stanford.edu/MainFolder/CoursePage.php?course=IntroToAlgorithms
4. https://www.coursera.org/specializations/algorithms

Activity Based Learning (Suggested Activities in Class)

1. Real world problem solving and puzzles using group discussion. E.g., Fake coin identification, Cabbage puzzle, Konigsberg bridge puzzle etc.,
2. Demonstration of solution to a problem through programming.

Skill Enhancement Course-II
Bosch Rexroth Innovation Lab
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER –IV

Course Code	:	23ME2408	**Credits**	:	2
Hours / Week	:	4 Hours	**Total Hours**	:	52 Hours
L–T–P–S	:	0–0–4–0			

Course Learning Objectives:

This Course will enable students to:

1. Design, evaluate, and troubleshoot hydraulic and pneumatic systems, making sure to choose the right parts including accumulators, actuators, valves, and pumps.
2. Build and test hydraulic and pneumatic circuits with a variety of parts and tools. Examine the outcomes to make sure the system satisfies the required performance standards.
3. Utilize analytical thinking and problem-solving techniques to identify and fix problems with pneumatic and hydraulic systems, guaranteeing maximum efficiency and security.
4. Encourage a culture of creativity and ongoing development in the fluid power industry by keeping abreast of emerging technologies and developments in pneumatics and hydraulics.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Interactive Lectures and Demonstrations*** means Deliver engaging lectures that illustrate the theoretical ideas of pneumatics and hydraulics with the help of practical examples and system and equipment demonstrations.
- ***Hands-On Laboratory Exercises:*** By holding lab sessions where students may construct, test, and troubleshoot hydraulic and pneumatic circuits using industry-standard tools, you can provide them practical experience.
- ***Problem-Based Learning:*** Involve students in problem-based learning exercises where they are presented with real-world problems and scenarios to address utilizing their hydraulics and pneumatics expertise.
- ***Collaborative Projects:*** Students can be required to design, develop, and present hydraulic and pneumatic systems as part of collaborative projects that promote teamwork. This encourages the sharing of ideas and peer learning.
- ***Technical Documentation and Reporting:*** Require students to keep thorough lab notebooks, write reports, and draw schematic diagrams for their experiments and projects in order to highlight the value of technical documentation.
- ***Safety Training***: To ensure that students comprehend the correct handling, use, and upkeep of hydraulic and pneumatic equipment, provide thorough safety instruction. Stress how crucial it is to follow safety procedures in the lab.
- ***Case Studies and Application Examples****:* Present case studies and examples of hydraulic and pneumatic systems in various industries, such as manufacturing, automotive, and aerospace, to illustrate the practical applications and significance of fluid power technology.
- ***Continuous Assessment and Feedback****:* - Use techniques for continual evaluation, such as lab reports, quizzes, and practical exams, to gauge students'

comprehension and development. Give pupils constructive criticism so they can get better.

BASIC & ELECTRO HYDRAULICS	20 Hours

- Characteristics of Industrial Hydraulics
  - Comparison of Hydraulics Vs. Electrical
  - Electronics, Pneumatics and Mechanical
  - Applications of Hydraulics
  - **Basic physical properties**
    i. Pressure.
    ii. Pascal's Law.
    iii. Force transmission
    iv. Pressure transmission
    v. Displacement Transmission
    vi. Flow rate and Flow Law.
- **Graphical Symbols and Hydraulic circuits.**
  - Hydraulic Fluids
  - Hydraulic pumps
  - Hydraulic Cylinder and Motor
- Hydraulic Control valves

i. PCV
ii. FCV
iii. DCV

BASIC & ELECTRO PNEUMATICS	32 Hours

  - Characteristics of Industrial Pneumatics
  - Comparison of Pneumatics Vs Electrical
- Electronics, Hydraulics and Mechanical
- Applications of Pneumatics
- Graphical Symbols and Pneumatic circuits.
- Generation of compressed air
- Processing of compressed air
- Maintenance unit
- Compressors
- Introduction to Relay Based Control System
- Function of Relays
- SPDT contacts
- Signal storage logic
- AND and OR logic

Hands-On-Training

Exercise 1: Extending a cylinder by operating a push button
Exercise 2: Signal storage by electrical self-locking, setting and resetting using a momentary-contact switch
Exercise 3: Mechanical locking by means of momentary-contact switch contacts
Exercise 4 Electrical locking by means of contactor contacts
Exercise 5: Signal storage by means of contactor contacts

Accumulator
Exercise 6: accumulator applications
Exercise 7: Pressure switches and proximity switches
Exercise 8: Advance control with time-dependent intermediate stop

Hands-On-Training

Exercise 1: Direct and indirect control of a single-acting cylinder, extending
Exercise 2: Direct and indirect control of a double-acting cylinder with pushbutton
Exercise 3: Signal storage by means of contactor contacts
Exercise 4: Controlling a double- acting cylinder, impulse valve, 2 push-buttons
Exercise 5: Displacement dependent control of a double acting cylinder, impulse valve
Exercise 6: Pressure-dependent control of 1 double-acting cylinder
Exercise 7: Time-dependent control of 1 double-acting cylinder
Exercise 8: Holding-element control of a double-acting cylinder with impulse valve, directly controlled
Exercise 9: Displacement-dependent control of a double-acting cylinder, impulse valve, cylinder switch
Exercise 10: Sequential control of 2 double-acting cylinders with impulse valves and signal overlapping
Exercise 11: Sequential control of 2 double-acting cylinders with spring return valves and step sequence

Course Outcome	Description
At the end of the course the student will be able to:	
1	Analyse the characteristics and applications of industrial hydraulics and pneumatics systems
2	Design and interpret hydraulic and pneumatic circuits using graphical symbols and standards
3	Evaluate the performance of hydraulic and pneumatic control valves and components through hands-on training exercises
4	Evaluate advanced control systems for hydraulic and pneumatic applications, incorporating time-dependent and displacement-dependent controls

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	1	1	2	2	-	-	2	2	-	-	-	1
CO2	2	2	2	2	-	-	-	2	1	-	-	-	2
CO3	1	1	1	2	-	-	-	2	1	-	-	-	2
CO4	1	1	1	2	-	-	-	2	1	-	-	-	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Text Books:

1. Hand Books & Manuals – Bosch Rexroth

EMBEDDED SYSTEMS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3501	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This course will enable students:

1. To provide in-depth knowledge of embedded system architecture relevant to mechanical engineering applications.
2. To enable students to interface and integrate sensors, actuators, and microcontrollers for automation tasks.
3. To train students in embedded programming for real-time control of mechanical systems.
4. To expose students to advanced embedded system design methodologies including safety and reliability.
5. To develop skills in applying embedded systems to solve complex industrial and automotive mechanical engineering problems.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.

UNIT – I	08 Hours

INTRODUCTION:

Introduction to Embedded Systems:

Definition and characteristics of embedded systems; Embedded systems in mechanical engineering: mechatronics, automotive, HVAC, robotics; Architecture of embedded systems: hardware, software, firmware; Applications and case studies relevant to mechanical

engineering.	
UNIT – II	**08 Hours**
Embedded Hardware Components: Microcontrollers (ARM, PIC, Arduino, STM32); Sensors: temperature, pressure, proximity, load cell, flow; Actuators: motors, solenoids, hydraulic & pneumatic actuators; Analog-to-Digital and Digital-to-Analog conversion; Power supplies and voltage regulation for embedded devices.	
UNIT – III	**08Hours**
Embedded Programming and Interfaces: Basics of embedded C and Arduino IDE; Digital I/O, PWM, Timers, Interrupts; Communication protocols: UART, SPI, I2C, CAN; Interfacing with motors and PID control; Data acquisition, filtering, and storage techniques.	
UNIT – IV	**07 Hours**
Control Systems & Real-Time Applications: Embedded control loops; Real-Time Operating Systems (RTOS) basics; Feedback control in robotics and automation; Safety and reliability considerations; Embedded system case studies in industrial machines, HVAC systems, and automotive systems.	
UNIT – V	**08 Hours**
Applications and Project Work: Automotive embedded systems (ABS, ECU, HVAC control); Industrial automation (CNC machines, PLC integration, robotic systems); Predictive maintenance using embedded monitoring; IoT integration for mechanical systems; Mini-project design and implementation.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Analyze the architecture and components of embedded systems for mechanical engineering applications.
2	Design sensor-actuator interfacing solutions for real-time monitoring and control in mechanical systems.
3	Evaluate embedded programming strategies for optimizing control performance in automation and robotics.
4	Integrate embedded systems into complex mechanical systems with safety, reliability, and efficiency considerations.
5	Formulate embedded-based solutions for predictive maintenance and industrial automation challenges.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	1	3	-	1	2	2	1	1	2	1
CO2	3	3	3	1	3	-	1	2	2	1	1	3	3
CO3	3	3	3	1	3	-	1	2	2	1	1	1	3
CO4	3	3	3	1	3	-	1	2	2	1	1	3	1
CO5	3	3	3	1	3	-	1	2	2	1	1	1	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS :

1. Raj Kamal, Embedded Systems: Architecture, Programming and Design, McGraw Hill Education (India) Private Limited, 2nd Edition, 2009.

2. K.V. Shibu, Introduction to Embedded Systems, McGraw Hill Education (India) Private Limited, 2nd Edition, 2016.

3. Frank Vahid and Tony Givargis, Embedded System Design: A Unified Hardware/Software Introduction, John Wiley & Sons, 2002.

REFERENCES :

1. Jonathan W. Valvano, Embedded Systems: Introduction to ARM Cortex-M Microcontrollers, CreateSpace Independent Publishing Platform, 2013.

2. Wayne Wolf, Computers as Components: Principles of Embedded Computing System Design, Morgan Kaufmann Publishers, 3rd Edition, 2012.

3. James K. Peckol, Embedded Systems: A Contemporary Design Tool, Wiley India Pvt Ltd, 2nd Edition, 2014.

4. David E. Simon, An Embedded Software Primer, Addison-Wesley, 2000.

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FINITE ELEMENT METHOD

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3502	**Credits**	:	04
Hours / Week	:	05 Hours	**Total Hours**	:	30+30 Hours
L–T–P–S	:	2–0–2–0			

Course Learning Objectives:

This course will enable students to:

1. Understand the fundamental principles and applications of computational methods like finite difference and finite volume methods in engineering analysis.
2. Develop proficiency in creating and manipulating element matrices for analyzing various physical phenomena including torsion, fluid flow, and heat transfer.
3. Gain practical skills in applying principles of virtual work, variational methods, and Galerkin's method to solve real-world engineering problems.
4. Master the use of finite element analysis for structural evaluation, including trusses, beams, and axi-symmetric stress analysis.
5. Learn to effectively utilize commercial finite element method (FEM) software for dynamic analysis, numerical integration, and error analysis.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of material testing of different metals and alloys

UNIT – I	05 Hours
Introduction to computational methods, Finite difference method, Finite volume methods, Direct stiffness method, Integral formulation for numerical Solution – Variational method, Method of weighted residuals, Potential energy formulations; Principle of virtual work, Division of the region into elements - One dimensional linear element, Linear triangular element, Bilinear rectangular element, Representation for scalar and vector	

fields, Global, local and natural coordinate systems in one, two and three dimensions.	
UNIT – II	**05 Hours**
Governing differential equations; Integral equations for the element matrices, Triangular element matrix, Torsion of noncircular sections, General theory – Twisting of a square bar, Shear stress components, Evaluation of the twisting torque, Flow of an Ideal Fluid – Potential Formulation, Groundwater Flow, Flow Around a Cylinder, Other field problems, Derivative boundary conditions – 1D, Derivative boundary conditions – 2D,	
UNIT – III	**05 Hours**
Heat transfer by conduction, The one-dimensional fin – 1, The one-dimensional fin –2, The composite walls, The two-dimensional fin, Boundary conditions, Long two-dimensional bodies – 1, Long two-dimensional bodies – 2, Axi-symmetric field problems, The differential equation – Axi-symmetric elements, Galerkin's method, Element matrices,	
UNIT – IV	**06Hours**
The axial force member - Element matrices, The truss element – Element matrices, Analysis of a pinned truss – 1, Analysis of a pinned truss – 2, A Beam element, Shape functions, Element matrices, Analysis of a statically indeterminate beam – 1, Analysis of a statically indeterminate beam – 2, A plane frame element – Element matrices, Two dimensional stress analysis - Stress, strain and Hooke's Law, The strain displacement equations, Two dimensional elasticity - Plane stress and plane strain, The displacement equations, The element matrices, Element stresses, Axi-symmetric stress analysis - Element matrices, Surface loads,	
UNIT – V	**05 Hours**
Iso-parametric elements in one and two dimensions, use of higher order elements, Element matrices, Introduction to Transient domain & Dynamic analysis, Changing the variables of integration- One-dimensional integrals, Two- dimensional integrals, Numerical Integration techniques- one-dimensional integrals, Quadrilateral regions, Triangular regions; Evaluating [B]; Evaluating the surface integrals, Pre and post processing, capability of commercially available FEM packages, Error analysis	

List of Laboratory/Practical Experiments activities to be conducted (if any) :30	
1.	Bars of constant cross section area, tapered cross section area and stepped bar
2.	Trusses (Minimum 2 exercises) Beams – Simply supported, cantilever, beams with UDL, beams with varying load etc; (Minimum 6 exercises)
3.	Dynamic analysis • Fixed – fixed beam for natural frequency determination • Bar Courseed to forcing function • Fixed – fixed beam Courseed to forcing function
4	Thermal Analysis – 1D & 2D problem with conduction and convection boundary conditions (Minimum 4 exercises)
5	Stress analysis of a rectangular plate with a circular hole

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Apply finite element methods such as finite difference and finite volume methods to solve complex engineering problems involving scalar and vector fields.
2	Develop and analyze element matrices and use computational techniques to

	evaluate torsion in non-circular sections and fluid flow scenarios.
3	Utilize advanced numerical methods to analyze heat transfer through various geometrical configurations, including fins and composite walls.
4	Implement structural analysis on trusses, beams, and frames using element matrices and evaluate the resulting stress and strain using Hooke's Law.
5	Perform dynamic and transient analysis using isoparametric elements and numerical integration techniques, ensuring accurate pre and post-processing in commercial FEM software.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	1	3	-	1	2	2	1	1	2	1
CO2	3	3	3	1	3	-	1	2	2	1	1	3	3
CO3	3	3	3	1	3	-	1	2	2	1	1	1	3
CO4	3	3	3	1	3	-	1	2	2	1	1	3	1
CO5	3	3	3	1	3	-	1	2	2	1	1	1	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. Segerlind, L. J (2006). Applied Finite Element Analysis. John Wiley and Sons.
2. Ramamurthy, G. (2009). Applied Finite Element Analysis. I.K. International Publishing House.

Reference Books:

1. Cook, R. D., Malkus, D. S., Plesha, M. E., & Witt, R. J. (2007). Concepts and Applications of Finite Element Analysis (4th ed., 1st reprint). Wiley Student Edition.
2. Rao, S. S. (2007). The Finite Element Method in Engineering. Butterworth-Heinemann (An imprint of Elsevier), Published by Elsevier India Pvt. Ltd.

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DESIGN OF MACHINE ELEMENTS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3503	**Credits**	:	04
Hours / Week	:	05 Hours	**Total Hours**	:	45+30 Hours
L–T–P–S	:	3–0–2–0			

Course Learning Objectives:

This course will enable students to:

1. Understand the stresses in machine members due to various types of loads and failure of components according to theories of failures.
2. Analyze the components under variable loading for infinite and finite life.
3. Design of machine elements under torsion, bending, axial loads and a combination of these.
4. Design of permanent and temporary joints and fasteners for a given load to be transmitted. Design of various screws, keys, coupling and shafts.
5. To understand use of different types of springs and determine safe design of spring under static and fluctuating loading conditions.
6. To understand the standard nomenclature, forces, failures, application, design procedure of Spur and Helical gears (As per AGMA)
7. To understand the standard nomenclature, forces, failures, application, design procedure of Bevel and Worm gears (As per AGMA) and to determine standard geometry under given loading condition
8. To understand the design procedure, failures and application of Ball Bearings and Sliding contact bearing
9. Design the clutches and brakes required for power transmission.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analyzing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.

- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of curved beam, journal bearing, shaft and gears

UNIT – I	08 Hours
Normal, shear, biaxial and triaxial stresses, factor of safety, stress concentration factor in tension, bending and torsion, theories of failures, static strength: static loads, impact strength: introduction, impact stresses due to axial, bending and torsional loads, Failure of brittle and ductile materials ***(text book-1: chapter 3: 3.10 to 3.13, chapter 5: 5.1 to 5.10)*** Introduction, S-N diagram, low cycle fatigue, high cycle fatigue, endurance limit, modifying factors: size effect, surface effect, stress concentration effects, fluctuating stresses, goodman and Soderberg relationship, stresses due to combined loading, cumulative fatigue damage. ***(Text Book-1: Chapter 6: 6.1 to 6.8)***	
UNIT – II	**08 Hours**
Threaded fasteners: stresses in threaded fasteners, effect of initial tension, design of threaded fasteners under static, dynamic and impact loads, design of eccentrically loaded bolted joints. ***(Text Book-1: Chapter 8: 8.1 to 8.12)*** Riveted and welded joints: types, rivet materials, failures of Riveted joints, joint efficiency, boiler joints, riveted brackets. Welded joints: types, strength of butt and fillet welds, eccentrically loaded welded joints. ***(Text Book-1: Chapter 9: 9.1 to 9.8***)	
UNIT – III	**08 Hours**
Joints: Types of keys, design of socket-spigot cotter joint, design of knuckle joint. Couplings: Types of couplings, design of flange and flexible couplings and muff coupling ***(Text Book-1: Chapter 8: 8.1 to 8.12***) Shafts: torsion of shafts, design for strength and rigidity with steady loading, ASME codes for power transmission shafting, shafts under fluctuating loads and combined loads. Curved beams: stresses in curved beams of standard cross sections used in crane hook ***(Text Book-1: Chapter 7: 7.1 to 7.8***)	
UNIT – IV	**08 Hours**
Springs: types, stresses in helical coil springs of circular and non-circular cross sections. Tension and compression springs, springs under fluctuating loads. Leaf springs: stresses in leaf springs. Equalized stresses, energy stored in springs, torsion. ***(Text Book-1: Chapter 10: 10.1 to 10.13***) Gears: Spur gears, Helical gears, Bevel Gears and Worm Gears: Definitions, stresses in gear tooth: Lewis's equation and form factor, design based on strength, dynamic and wear loads, formative number of teeth, formative number of teeth, efficiency of worm gear drives ***(Text Book-1: Chapter 13: 13.1 to 13.11***)	
UNIT – V	**07 Hours**
Bearings: lubricants and their properties, mechanisms of lubrication bearing modulus, coefficient of friction, minimum oil film thickness, heat generated, heat dissipated, bearing materials, examples of journal bearing and thrust bearing design. ***(Text Book-1: Chapter 12:12.1 to 12.15***) Clutches & Brakes: Design of clutches: Single plate, multi plate and cone clutches. Design of Brakes: Block and band brakes: Self-locking of brakes: Heat generation in brakes. ***(Text Book-1: Chapter 16: 16.1 to 16.10***)	
LIST OF LABORATORY/PRACTICAL EXPERIMENTS ACTIVITIES TO BE CONDUCTED: 30 HRS	
1. Determination of principal stresses and strains in a member Courseed to combined Loading using strain rosettes and verification using FEA tool.	

2. Determination of critical speed of a rotating shaft and verification using FEA tool.
3. Determination of stresses in curved beam using strain gauge and verification using FEA tool.
4. Design of shafts to direct and combined loading for given loads and conditions and comparing design by using CAD/CAE software.
5. Determination of pressure distribution in journal bearing
6. Modelling and stress analysis of spur and helical gear tooth by using CAD/CAE software
7. Modelling and stress analysis of helical and leaf springs using CAD/CAE software
8. Modelling and stress analysis of brake by using CAD/CAE software
9. Modelling and stress analysis of single plate and multi-plate clutches by using CAD/CAE software

Course Outcome	Description
At the end of the course the student will be able to:	
1	Calculate various stresses, factors of safety, and predict failure modes under combined loading conditions.
2	Design and analyse threaded fasteners and bolted, riveted, and welded joints under various loading conditions, considering joint efficiency and failure modes.
3	Design and analyse various types of mechanical joints, couplings, shafts, curved beams, springs, and gears under different loading conditions, ensuring strength, rigidity, and efficiency.
4	Analyse bearing designs considering lubrication and heat management, and design various clutches and brakes, focusing on performance and self-locking mechanisms.
5	Apply CAD/CAE software and experimental methods to determine and analyse stresses, pressure distribution, and critical speeds in various mechanical components, including shafts, bearings, gears, springs, brakes, and clutches under different loading conditions.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	3	-	2	2	-	-	-	-	1	3
CO2	3	3	3	3	-	2	2	-	-	-	-	1	3
CO3	3	3	3	3	-	2	2	-	-	-	-	1	3
CO4	3	3	3	3	-	2	2	-	-	-	-	1	3
CO5	3	3	3	3	-	2	2	-	-	-	-	1	3
CO6	3	3	3	3	3	2	2	3	3	-	3	3	3

TEXT BOOKS:

1. Shigley, J. E., Mitchell, L. D., & Saunders, H. (1985). Mechanical engineering design.
2. Bhandari, V. B. (2010). Design of machine elements. Tata McGraw-Hill Education.

REFERENCE BOOKS:

1. Norton, R. L. (2010). Machine design. London, UK: Prentice Hall.
2. M. F. Spotts, T. E. Shoup, L. E. Hornberger, S. R. Jayram and C. V. Venkatesh (2019) Design of Machine Elements Pearson Education, Eighth edition.

E-Resources:

1. https://nptel.ac.in/courses/112/105/112105124/
2. https:// nptel.ac.in/courses/112/106/112106137/

INDUSTRIAL AUTOMATION AND ROBOTICS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3504	**Credits**	:	03
Hours / Week	:	04 Hours	**Total Hours**	:	30+30 Hours
L–T–P–S	:	2–0–2–0			

Course Learning Objectives:

This Course will enable students to:

1. Gain a comprehensive understanding of the fundamental concepts, history, and applications of robotics and automation in various industries.
2. Acquire knowledge and skills in the mechanical design of robotic systems, including kinematics, dynamics, and the selection of actuators and end-effectors.
3. Learn to program and interface robots using popular robotics programming languages and software, such as Python and ROS.
4. Understand the role and function of programmable logic controllers (PLCs) and how they integrate with robotic systems for enhanced automation solutions.
5. Study advanced applications and emerging trends in robotics, such as collaborative and mobile robotics, and assess their future impact on mechanical engineering**.**

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I Introduction to Automation and Robotics	**05 Hours**
Overview of automation and robotics in industry; history and evolution of robotic systems; types of robots and their applications.	
UNIT – II Mechanical Design of Robotic Systems	**05 Hours**
Design principles of robotic systems; kinematics and dynamics of robots; end-effectors and actuators.	
UNIT – III Robotics Programming and Interfaces	**05 Hours**
Introduction to programming languages for robots (e.g., Python, ROS); interfacing with sensors and actuators.	
UNIT – IV Automation Technologies	**06 Hours**
Overview of automation technologies; PLCs and their role in automation; integration of robotic systems with manufacturing processes.	
UNIT – V Advanced Applications and Emerging Trends	**05 Hours**
Advanced robotic applications (collaborative robots, mobile robots); emerging trends in robotics and future implications for mechanical engineering.	

Sl. No	**List of Laboratory/Practical Experiments activities to be conducted (if any) Total 30 Hrs**
1	Basic safety training; introduction to robotic simulation software; simple tasks using robotic arms in simulation.
2	Design and simulation of a robotic arm; calculation of degrees of freedom and range of motion; hands-on assembly of small robotic kits.
3	Programming a robotic arm to perform specific tasks; sensor integration and basic task automation.
4	PLC programming basics; creating control logic for automated sequences; interfacing PLCs with robotic arms.
5	Experimentation with collaborative robots; introduction to mobile robotics and navigation algorithms; project presentations on innovative robotic solutions.

Course Outcome	**Description**
1	Apply fundamental robotics principles to design, analyse, and improve automation systems in mechanical engineering contexts.
2	Demonstrate proficiency in programming and interfacing robotic systems for task-specific applications using industry-standard software.
3	Integrate sensors, actuators, and controllers to develop comprehensive robotic systems that meet engineering specifications.
4	Implement PLC programming and control logic to automate processes within robotic systems efficiently.
5	Evaluate and adopt emerging robotic technologies, such as collaborative and mobile robots, for innovative mechanical engineering solutions.

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
COs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	2	2	2	-	1	-	-	-	-	-	1	1	1
CO2	3	3	2	-	3	-	-	-	-	-	1	1	1
CO3	3	2	3	-	2	-	-	-	-	-	1	1	1
CO4	3	3	3	-	3	-	-	-	-	-	1	1	1
CO5	3	2	3	-	1	-	-	-	-	-	1	1	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. John J. Craig. (2017) Introduction to Robotics: Mechanics and Control by Pearson, 4th Edition,.
2. Corke, P. (2021). Robotics and control: fundamental algorithms in MATLAB® (Vol. 141). springer Nature.

Reference Books:

1. Mikell P. Groover (2014) "Automation, Production Systems, and Computer-Integrated Manufacturing" by, Prentice Hall, 4th Edition.
2. Corke, P. (2021). Robotics and control: fundamental algorithms in MATLAB® (Vol. 141). springer Nature.

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THERMAL MANAGEMENT OF ELECTRONIC DEVICES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3505	**Credits**	:	03
Hours / Week	:	04 Hours	**Total Hours**	:	30+30 Hours
L–T–P–S	:	2–0–2–0			

Course Learning Objectives:

This course will enable students to:

1. Appreciate the importance of thermal management for the performance and reliability of electronic devices
2. Identify how temperature impacts failure modes and component lifespan in electronic systems.
3. Utilize conduction, convection, and radiation principles in designing thermal management solutions
4. Evaluate and select appropriate cooling methods based on performance requirements and cost-effectiveness.
5. Apply simulations to optimize cooling strategies, predict temperature distributions, and evaluate thermal management effectiveness

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of material testing of different metals and alloys

UNIT – I	**05 Hours**
INTRODUCTION TO THERMAL MANAGEMENT: Understanding the critical role of thermal management in electronics, its impact on performance, reliability, and overall system lifespan. Overview of economic and operational consequences of thermal issues. **TEMPERATURE EFFECTS ON FAILURE MODES:** Exploration of how temperature affects failure mechanisms like thermal stress, fatigue, electromigration, and material expansion in electronic components.	
UNIT – II	**05 Hours**
CONDUCTION COOLING AND HEAT SINKS Study of materials and thermal interface materials (TIMs) used to enhance heat conduction in electronic systems **HEAT SINK DESIGN:** Core principles of heat sink design, including material choice, geometry, and surface treatments. examination of advanced configurations like pin-fin and vapor chamber heat sinks. **CONVECTION COOLING:** Overview of natural and forced convection cooling methods, focusing on fan selection, placement, and optimization for effective airflow management.	
UNIT – III	**06 Hours**
LIQUID COOLING TECHNIQUES Introduction to liquid immersion cooling, its principles, and the selection of appropriate dielectric fluids for high-performance applications, Flow-Through Cooling for Circuit Card Assemblies (CCAs) **COLD WALL COOLING AND COLD PLATES:** Exploration of cold wall cooling and cold plate designs, their applications, and integration into electronic systems for enhanced heat dissipation.	
UNIT – IV	**05 Hours**
ADVANCED AND EMERGING COOLING TECHNOLOGIES Principles and applications of jet impingement and synthetic jet cooling, focusing on their use for localized, high-efficiency cooling. Thermoelectric (Solid-State) Coolers **COOLING USING PHASE CHANGE MATERIALS (PCM):** Use of phase change materials in thermal management, including selection criteria and integration techniques.	
UNIT – V	**05 Hours**
MICRO/MINI CHANNEL COOLING: Applications of micro/mini channel cooling technologies in high-density and high-power electronics. **HEAT PIPES:** Study of heat pipe principles, working fluids, and their integration into thermal management systems for efficient heat transfer.	
LIST OF LABORATORY/PRACTICAL EXPERIMENTS ACTIVITIES TO BE CONDUCTED (IF ANY) **TOTAL 30 HRS**	
1. Simulate heat conduction through different materials and geometries using MATLAB, Study the effect of material properties (thermal conductivity) and boundary conditions on temperature distribution 2. CFD Analysis of Forced Convection Cooling: Analyze fluid flow and heat transfer in electronic cooling applications using CFD software (e.g., ANSYS Fluent)	

3. Liquid Cooling System Simulation using Matlab and CFD: Develop a thermal model of a liquid cooling loop incorporating components like pumps, heat exchangers, and flow control valves using Matlab.
4. Heat Pipe Simulation and Analysis: Simulate heat transfer in a heat pipe and analyze its effectiveness in thermal management.

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply the fundamental concepts of thermal management to assess their impact on the performance and reliability of electronic devices
2	Design and Evaluate heat sinks with optimal material choice, geometry, and surface treatments, including advanced configurations like pin-fin and vapor chamber heat sinks
3	Evaluate and Optimize different cooling methods, including heat sinks, liquid cooling, and advanced technologies like thermoelectric coolers and heat pipes, to enhance thermal performance
4	Analyse micro/mini channel cooling technologies to manage heat dissipation in high-density and high-power electronic applications
5	Simulate and Predict the thermal behaviour of electronic systems using MATLAB and CFD tools to develop and refine cooling strategies

Table: Mapping Levels of COs to POs / PSOs													
COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	2	2	-	1	-	-	-	-	-	1	1	1
CO2	3	3	2	-	3	-	-	-	-	-	1	1	1
CO3	3	2	3	-	2	-	-	-	-	-	1	1	1
CO4	3	3	3	-	3	-	-	-	-	-	1	1	1
CO5	3	2	3	-	1	-	-	-	-	-	1	1	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Frank P. Incropera and David P. DeWitt (2006) “Fundamentals of Heat and Mass Transfer”, 6th Edition, John Wiley & Sons, Inc.
2. D. Steinberg (1991). Thermal Management of Electronic Systems" John Wiley & Sons.

REFERENCE BOOKS:

1. Andreas C. Papadakis (2015) "Thermal Design and Thermal Behaviour of Radio Frequency Devices" - CRC Press.

E-Resources:

1. https://nptel.ac.in/courses/113107078
2. https://nptel.ac.in/courses/103105219
3. https://nptel.ac.in/courses/112107221
4. https://www.coursera.org/learn/crystal-structures-and-properties-of-metals?

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Skill Enhancement Course-III
CAE LAB-I (CATIA)

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3507	**Credits**	:	02
Hours / Week	:	04 Hours	**Total Hours**	:	52 Hours
L–T–P–S	:	0–0–4–0			

Course Learning Objectives:

This Course will enable students to:

1. Develop proficiency in using CATIA software for creating and editing 2D sketches and 3D models.
2. Equip students with the skills to design and modify complex parts and assemblies using CATIA's part and assembly workbenches.
3. Enhance students' ability to create and manage detailed surface models and perform advanced surface operations.
4. Prepare students to generate professional engineering drawings and documentation, including standard views, dimensions, and annotations, using CATIA's drafting tools.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I: Introduction to CATIA	10 (lab) Hours
• Overview of CATIA interface and functionalities. • Basics of 2D sketching: creating and editing sketches. • Constraints and dimensions in sketches. • Simple sketch-based features: extrude, revolve, and sweep.	
UNIT – II: Part Design Fundamentals	**10 Hours**

• Introduction to part design workbench. • Creating and modifying basic solid features: pads, pockets, shafts, and grooves. • Boolean operations: add, subtract, and intersect. • Creating complex geometries using multi-section solid features.	
UNIT – III: Assembly Design	**10 Hours**
• Introduction to assembly workbench and its interface. • Creating and managing assembly components. • Applying constraints to assemble parts accurately. • Techniques for managing large assemblies.	
UNIT – IV: Surface Design	**12Hours**
• Introduction to generative shape design workbench. • Creating and editing basic surfaces: extrude, revolve, sweep, and loft. • Surface operations: trim, split, join, and fillet. • Advanced surface modeling techniques.	
UNIT – V: Drafting and Documentation	**10 Hours**
• Introduction to drafting workbench and its tools. • Creating standard views from 3D models. • Adding dimensions, annotations, and symbols to drawings. • Generating bill of materials (BOM) and creating detailed engineering drawings.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	**Create** and **manipulate** complex 2D sketches and 3D models using CATIA's sketching and part design tools to meet specific design requirements.
2	**Construct** and **optimize** intricate assemblies by applying appropriate constraints and managing large assemblies efficiently within CATIA.
3	**Design** and **refine** advanced surface models, employing a variety of surface operations to achieve precise and complex geometries.
4	**Generate** and **evaluate** comprehensive engineering drawings and documentation, ensuring accuracy and adherence to industry standards using CATIA's drafting tools.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	2	2	-	2	-	-	2	1	-	-	2	2
CO2	1	2	2	1	2	-	-	2	1	-	-	2	2
CO3	1	2	2	2	-	1	-	2	1	-	-	2	2
CO4	1	2	2	2	2	-	-	2	1	-	-	2	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Text Books:

1. Tickoo Sham, (2016)"CATIA V5-6R2015 Basics: Sketcher, Part, and Assembly Design" CADCIM Technologies.

Reference Books:

1. Richard Cozzens (2013) "CATIA V5 Workbook Release V5-6R2013", SDC Publications.

Skill Enhancement Course-III
CAE LAB-II (ANSA)

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3508	**Credits**	:	02
Hours / Week	:	04 Hours	**Total Hours**	:	52 Hours
L–T–P–S	:	0–0–4–0			

Course Learning Objectives:

This Course will enable students to:

1. Enable students to learn and apply ANSA – a finite element pre-processor for industry problems
2. Enable students to learn the process for complex FEM (Finite Element Modelling) for structural and CFD analyses using 2D & 3D elements for selected industry problems, including how to model mechanical joints (welds, bolts, rivets etc.), mid-surface extraction, joining of different sub-systems, basic quality checks etc.
3. Full model checks as per the industry standards

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	10 Hours

• Introduction to FEA
Overview of FEA with some basic examples and explaining the importance of mathematical model generation to carry out different analyses
• Reading and translation of CAD files and introduction to TOPO menu
Main terms of TOPO Menu, changing FEM disciplines between different menus, Geometry clean up, preparing model for surface meshing,
switch to Mesh menu and explain about some basic options in Mesh menu

ex: perimeters, macros, mesh generator etc. • Meshing for Sheetmetal and plastic parts Middle Surface Extraction approach like Skin and Casting, Mesh generation and Quality corrections	
UNIT – II	**10 Hours**
Introduction to Part Manager, Property and Material assignment Creating parts, groups and meta data carried from CAD software, assigning property and materials for entities • Handling of Sheetmetal features Identification of features like holes, stamps, beads etc, and definition of design actions, mesh treatment. Collaboration of feature manager with morphing module. • Connections of Parts Overview of connection manager, different types of weld representation (seam weld, spot weld), and bolt definition (both 1D and 3D) • Boundary condition for static load case Preparing model to carry out linear load case like SPC, load definition (point load and distributed load), header creation and output the file in industry standard solver format	
UNIT – III	**10 Hours**
Tetrahedral and Hexahedral mesh generation Typical solid parts demonstration to generate 2D tria mesh and convert them to tetra mesh. Overview of map, extrude, solid build options and mesh quality corrections.	
UNIT – IV	**10 Hours**
Hybrid mesh generation for CFD external aerodynamics Geometry healing, batch mesh scenarios, quality corrections, mesh refining process like size box and layer generation. Overview of interfaces using property cards. 3D model generation with solution details.	
UNIT – V	**12 Hours**
•Morphing module for design modifications DFM (Direct Fit Morphing) options like rotate, translate, glide, sweep etc for external aerodynamics 2D mesh model • Coupling of ANSA with optimizers Creation of parameters, DOE (Design of Experiments) for linear cases	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply FEA principles to read, translate, and prepare CAD models for meshing, including geometry cleanup and mesh generation for sheet metal and plastic parts.
2	Design and manage parts using modeling tool, including property and material assignment, handling sheet metal features, and defining connections such as welds and bolts.
3	Generate tetrahedral and hexahedral meshes for solid parts, perform quality corrections, and apply hybrid mesh generation techniques for CFD external aerodynamics.

4	Utilize the morphing module for design modifications and integrate CATIA with optimizers to perform design of experiments (DOE) for linear cases.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	1	2	2	-	2	-	-	2	1	-	-	2	2
CO2	1	2	2	1	2	-	-	2	1	-	-	2	2
CO3	1	2	2	2	-	1	-	2	1	-	-	2	2
CO4	1	2	2	2	2	-	-	2	1	-	-	2	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Reference Book:

1: ANSA version 22 Tutorial Guide - 2021

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Skill Enhancement Course-III
ABAQUS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3509	**Credits**	:	02
Hours / Week	:	04 Hours	**Total Hours**	:	52 Hours
L–T–P–S	:	0–0–4–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the fundamentals of finite element modeling and simulation using ABAQUS.
2. Apply ABAQUS to build geometric models, assign materials, and define boundary conditions.
3. Conduct static structural, thermal, and contact analysis using ABAQUS solver.
4. Interpret and validate simulation results through post-processing techniques.
5. Apply simulation-based problem solving for real-world engineering design and failure analysis

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	**10 Hours**

Introduction to Finite Element Analysis and ABAQUS Interface

Week 1:
Introduction to FEA: Concept, Applications, Limitations
ABAQUS Interface: Modules, GUI Overview, Navigation

Week 2:
Building Simple Geometries, Part Module, Assembly Concepts
Assignments/Project:

Build basic 2D and 3D geometry models in ABAQUS.	
UNIT – II	**10 Hours**
Material Definition, Boundary Conditions and Meshing Week 3: Defining Material Properties: Linear Elastic, Plasticity, Thermal Week 4: Applying Loads, Boundary Conditions and Constraints Week 5: Meshing: Element Types, Mesh Quality, Mesh Refinement Assignments/Project: Prepare multiple models with proper material definition, meshing, and boundary conditions.	
UNIT – III	**10 Hours**
Static Structural Analysis Week 6: Setting up Static Analysis: Step Module, Solver Settings Week 7: Analysis of Beams, Plates, Shells under Loading Conditions Week 8: Post-processing: Stress, Strain, Displacement Interpretation Assignments/Project: Perform full structural analysis of machine components with validation.	
UNIT – IV	**10 Hours**
Contact, Assembly & Thermal Analysis Week 9: Contact Interactions: Friction, Hard and Soft Contact, Assembly Analysis Week 10: Introduction to Thermal Analysis: Steady-State and Transient Week 11: Combined Analysis: Thermal-Stress Coupled Problems Assignments/Project: Simulate contact problems and thermal loading cases on assemblies.	
UNIT – V	**12**

	Hours
Case Studies, Optimization and Project Work Week 12: Case Studies on Industrial Problems: Design Validation, Failure Analysis Week 13: Project Presentation, Simulation Report Preparation, Review Assignments/Project: Complete a comprehensive real-world FEA problem involving structural and thermal simulation using ABAQUS.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Understand the basics of FEA and use ABAQUS interface for model building.
2	Define material properties, apply loads, boundary conditions, and generate high-quality meshes.
3	Conduct static structural analysis and interpret simulation results.
4	Perform advanced simulations involving contact, assembly, and thermal analysis.
5	Execute complete simulation projects involving problem definition, model building, analysis, result validation and report preparation.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	2	2	-	2	-	-	2	1	-	-	2	2
CO2	1	2	2	1	2	-	-	2	1	-	-	2	2
CO3	1	2	2	2	-	1	-	2	1	-	-	2	2
CO4	1	2	2	2	2	-	-	2	1	-	-	2	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Text Books:

1. Finite Element Analysis Using ABAQUS: Practical Guide by S. R. Hibbeler, Pearson.
2. Introduction to Finite Element Analysis Using ABAQUS by Aslam Kassimali, Cengage Learning.

Reference Books:

1. Practical Finite Element Analysis for Mechanical Engineers by Finite Element Center, CADFEM.
2. Finite Element Analysis: Theory and Application with ABAQUS (2nd Edition) by Saeed Moaveni, Pearson.

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PROFESSIONAL ELECTIVE-1

Sensors & Actuators

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3510	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the fundamental principles and characteristics of various sensors and actuators used in mechanical systems.
2. Analyze the performance parameters and control mechanisms of sensors and actuators to optimize their applications in engineering solutions.
3. Explore advanced sensor technologies and their integration into mechanical systems for enhanced functionality and reliability.
4. Evaluate the theoretical aspects of sensor and actuator networks, including smart sensors and IoT applications in mechanical engineering.
5. Critically assess real-world case studies to understand the practical implications and ethical considerations of deploying sensors and actuators in industry.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : Principles of Sensors	**09 Hours**
Introduction to Sensors: Definitions, classifications, and roles in mechanical systems. Sensor Characteristics: Accuracy, sensitivity, range, resolution, and repeatability. Mechanical and Electromechanical Sensors: Emphasis on strain gauges, accelerometers, and pressure sensors. Theoretical Foundations: Understanding the physics and mechanics behind sensor operation.	
UNIT – II: Principles of Actuators	**09 Hours**
Introduction to Actuators: Overview of types and applications in mechanical engineering. Mechanical Actuators: Detailed theory on hydraulic, pneumatic, and electromechanical actuators. Performance Parameters: Force, speed, energy efficiency, and control characteristics. Theoretical Analysis: Studying the mechanical principles that govern actuator performance.	
UNIT – III: Sensor and Actuator Control Theory	**06 Hours**
Control Systems Overview: Basics of control theory relevant to sensors and actuators. Feedback and Feedforward Control: Understanding how these systems are applied in mechanical contexts. Dynamic Behavior of Actuators: Modeling and simulation of actuators under various control strategies. Theoretical Exercises: Analyzing control system designs through theoretical problems and simulations.	
UNIT – IV: Advanced Sensor Technologies	**07 Hours**
Smart Sensors and IoT: Concepts of smart sensors, integration with IoT, and implications for mechanical systems. Wireless Sensor Networks (WSN): Theoretical basis for design and implementation of WSNs. Sensor Fusion: Techniques for combining multiple sensor outputs to improve accuracy and reliability. Discussion on Emerging Technologies: Focus on MEMS, nanosensors, and their impact on mechanical engineering.	
UNIT – V: System Integration and Case Studies	**08 Hours**
Designing Integrated Systems: Theoretical approaches to integrating sensors and actuators into mechanical systems. Case Studies: Examination of real-world applications in automotive, aerospace, and industrial automation. Ethical and Environmental Considerations: Discussing the implications of sensor and actuator technology in mechanical engineering. Review and Future Trends: Exploring current research and future directions in sensor and actuator technology.	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Apply knowledge of sensor and actuator characteristics to select appropriate technologies for specific mechanical engineering applications.
2	Design and analyze control systems for actuators using advanced control theories to ensure optimal performance in mechanical setups.
3	Apply and configure smart sensors and wireless networks in mechanical systems, demonstrating an understanding of complex system requirements and functionalities
4	Apply information from diverse sensor inputs through sensor fusion techniques to improve system accuracy and reliability in engineering projects

5	Evaluate and propose improvements to existing sensor and actuator systems in mechanical engineering case studies, focusing on sustainability and ethical considerations.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	1	2	2	2	1	-	-	-	-	-	2	1	1
CO2	2	2	3	2	2	-	-	-	-	-	-	1	2
CO3	1	1	1	1	1	-	-	-	-	-	-	1	2
CO4	1	2	2	1	2	1	-	-	-	-	-	1	2
CO5	1	1	1	2	-	-	-	-	-	-	-	1	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Text Books:

1. Clarence W. de Silva (2015)."Sensors and Actuators: Engineering System Instrumentation", CRC Press, 2nd Edition.
2. W. Bolton, (2015) "Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering", Pearson, 6th Edition.

References:

1. David G. Alciatore and Michael B. Histand (2018) "Introduction to Mechatronics and Measurement Systems", McGraw-Hill Education, 5th Edition.
2. Placko, D. (Ed.). (2013). Fundamentals of instrumentation and measurement. John Wiley & Sons.

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AUTOMATED MANUFACTURING SYSTEMS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3511	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Introduce students to the fundamental concepts and components of automated manufacturing systems.
2. Provide knowledge on the configuration, programming, and control of industrial robots.
3. Explain the principles and implementation of computer-integrated manufacturing systems.
4. Teach the design and application of various automated material handling systems.
5. Equip students with the skills to apply quality control and monitoring techniques in automated manufacturing environments.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible,it helps improve the students' understanding.

UNIT – I : Introduction to Automated manufacturing Systems	**09 Hours**
Overview of manufacturing systems. Evolution and types of automation. Key components of automated systems. Role of automation in manufacturing. Economic and strategic importance	
UNIT – II: Industrial Robotics and Automation	**09 Hours**

Basics of industrial robotics. Robot configurations and applications. Robotic work cells and their integration. Programming and controlling robots. Safety and maintenance of robotic systems	
UNIT – III: Computer-Integrated Manufacturing (CIM)	**06 Hours**
Concepts of CIM. Components of CIM: CAD, CAM, and CAPP. CIM architecture and data flow Integration of CIM with ERP and MES. Benefits, challenges, and case studies	
UNIT – IV: Automated Material Handling Systems	**07 Hours**
Types of material handling systems. Automated storage and retrieval systems (AS/RS). Conveyors, AGVs, and industrial trucks. Design principles and implementation. Case studies and applications	
UNIT – V: Quality Control and Monitoring in Automated Systems	**08 Hours**
Principles of quality control in manufacturing. Automated inspection and testing techniques. Role of sensors and data acquisition systems. Statistical process control (SPC) and its applications. Quality management systems (QMS)	

Course Outcome	Description
1	**Differentiate** various types of automated manufacturing systems and their key components, highlighting their roles in production processes.
2	**Analyze** the configurations and applications of industrial robotics, assessing their integration within automated work cells.
3	**Evaluate** the components of Computer-Integrated Manufacturing (CIM), including CAD, CAM, and CAPP, and their impact on manufacturing efficiency.
4	**Examine** different automated material handling systems, focusing on design principles and implementation strategies for operational effectiveness.
5	**Assess** quality control principles in automated systems, utilizing statistical process control and automated inspection techniques to ensure manufacturing quality.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	1	1	-	-	1	-	-	-	-	-	1	1
CO2	2	2	2	2	2	-	-	2	2	-	1	2	2
CO3	2	2	2	2	2	-	-	-	-	-	1	3	3
CO4	2	2	2	2	-	-	-	-	-	-	1	-	-
CO5	2	2	2	2	2	-	-	-	-	-	-	-	-

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks

1. Mikell P. Groover (2014)"Automation, Production Systems, and Computer-Integrated Manufacturing"4th edition Pearson.
2. John J. Craig (2017) "Introduction to Robotics: Mechanics and Control" Pearson Education.

Reference Books

1. Siciliano, B., Sciavicco, L., Villani, L., & Oriolo, G. (2009). Robotics: Modelling, Planning and Control. Springer.

2. Groover, M. P. (2020). Fundamentals of Modern Manufacturing: Materials, Processes, and Systems (6th ed.). Wiley.

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INTRODUCTION TO HYBRID & ELECTRIC VEHICLES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3512	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This course will enable students to:

1. Explain the basics of electric and hybrid electric vehicles, their architecture
2. Discuss the design and component sizing and the power electronics devices used in electric and hybrid electric vehicles.
3. Analyse various electric drives suitable for electric and hybrid electric vehicles.
4. To help the students for understanding the concept of powertrain sizing and energy management system
5. Understanding of different energy storage technologies and power electronics system used for electric and hybrid electric vehicles

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of material testing of different metals and alloys

UNIT – I	09 Hours

HYBRID VEHICLE ARCHITECTURE:

Introduction - Concept of Hybrid Electric Drivetrains - Architectures of Hybrid Electric Drivetrains - Series and Parallel Hybrid Electric Drivetrains – Coupling Modes - Operating Modes – Hybridization factor – PHEV – Performance characteristics

Electric Vehicle Architecture:

Introduction- Configurations - Traction Motor Characteristics - Tractive Effort and

Transmission Requirement – Power Flow Control in Electric Drivetrain – Positioning of Motors – Vehicle Performance - Tractive Effort in Normal Driving - Energy Consumption – Single and Multi-Motor drives.	
UNIT – II	**09 Hours**
POWERTRAIN COMPONENTS OF HYBRID AND ELECTRIC VEHICLES: Traction Motor Types – Configuration and Control - DC Motor- Brushless DC Motor – BLDC Motor Control - Switched Reluctance Motor – AC Induction – Motor Drives and Introduction to Power electronic components – Electronic Control Unit of Motors – Various Control Modes – Drive system Efficiency **SIZING OF POWERTRAIN SYSTEMS:** Fundamentals of Vehicle Propulsion – Vehicle Resistance – Basics - sizing and rating of powertrain components - Introduction to tractive force- torque and power - Basics and factors influenced on tractive force- torque and power (2w, 3w &4w) - Calculation of battery pack- motor torque and power requirements for EV-Case study – Operating fuel economy	
UNIT – III	**06 Hours**
POWERTRAIN ENERGY MANAGEMENT SYSTEM Introduction to energy management strategies - classification of energy management strategies -rule based and optimization strategies - real-time working of energy management system in HEV -model-based design and simulation process - Implementation issues of energy management strategies	
UNIT – IV	**08 Hours**
TRANSMISSION SYSTEM FOR HYBRID AND ELECTRIC POWERTRAIN: Need for transmission system in EV and HEV – Torque and Speed Matching - Design consideration of transmission system - Types and Procedure, Power Transmission – Power flow and management, Powertrain components for series -parallel - series-parallel hybrid- Power and Torque distribution- Types of transmission - Single Speed – Multi-speed transmission in EV-Planetary Gear box in HEV- Drive shaft in EV and HEV	
UNIT – V	**07 Hours**
ENERGY STORAGE SYSTEM AND POWER ELECTRONICS IN EV AND HEV Batteries – Ultracapacitor -Supercapacitor - Fuel Cells, and Controls - Flywheel Energy Storage - Hydraulic Energy Storage - Hybrid Fuel Cell Energy Storage. Power electronics including switching - AC-DC, DC-AC conversion - electronic devices and circuits used for control and distribution of electric power- Thermal Management of HEV Power Electronics	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Analyze the architecture and performance characteristics of hybrid and electric vehicle drivetrains.
2	Evaluate the efficiency and control modes of different traction motors used in hybrid and electric vehicles.
3	Design and size powertrain components for hybrid and electric vehicles based on vehicle propulsion fundamentals and tractive force requirements.

4	Implement and optimize energy management strategies for hybrid and electric vehicle powertrains in real-time applications.
5	Assess the design considerations, power flow, and transmission systems used in hybrid and electric vehicles, including single and multi-speed transmissions and energy storage systems.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	1	2	2	2	1	-	-	-	-	-	2	1	1
CO2	2	3	2	2	2	-	-	-	-	-	-	1	2
CO3	1	1	1	1	1	-	-	-	-	-	-	1	2
CO4	1	2	2	1	2	1	-	-	-	-	-	1	2
CO5	1	1	1	2	-	-	-	-	-	-	-	1	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Chris Mi (2017), Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives, Wiley

REFERENCE BOOKS:

1. Ehsani, M., Gao, Y., Longo, S., & Ebrahimi, K. M. (2018). Modern electric, hybrid electric, and fuel cell vehicles. CRC press
2. Denton, T. (2020). Electric and hybrid vehicles. Routledge

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SOLAR ENERGY ENGINEERING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3513	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Estimate solar radiation using models and empirical methods
2. Explain the operation principles of various solar thermal collectors
3. Perform performance analysis of PV systems under different environmental conditions
4. Integrate energy storage solutions into solar energy systems, select appropriate storage technologies based on application requirements
5. Assess diverse applications of solar energy in heating, cooling, and power generation

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	08 Hours

FUNDAMENTALS OF SOLAR ENERGY:

Solar radiation basics: nature, composition, and solar constant, Geometric relations: incidence, azimuth, zenith angles, Solar radiation measurement techniques: pyranometers, pyrheliometers, Models and methods for estimating solar radiation

UNIT – II	08 Hours

SOLAR THERMAL ENERGY SYSTEMS:

Types of solar collectors: flat-plate, evacuated tube, concentrating, Thermal performance metrics and efficiency parameters, Heat transfer mechanisms: conduction, convection, radiation, Design and optimization of solar thermal systems

UNIT – III	06 Hours
SOLAR PHOTOVOLTAIC SYSTEMS: Photovoltaic (PV) principles: photoelectric effect, solar cell operation, Types of PV technologies: crystalline silicon, thin-film, emerging technologies, Components of PV systems: panels, inverters, batteries, Design and performance analysis of PV systems	
UNIT – IV	**08 Hours**
SOLAR ENERGY STORAGE AND CONVERSION: Thermal energy storage methods: sensible and latent heat storage, Electrical energy storage: battery technologies, Conversion technologies: converting stored solar energy,Integration strategies for enhanced system performance	
UNIT – V	**09 Hours**
APPLICATIONS AND ECONOMICS OF SOLAR ENERGY: Solar heating and cooling applications, Solar power generation: residential, commercial, utility-scale. Economic analysis: cost-benefit, payback period, LCOE Policy impact: government incentives, regulations	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Evaluate solar radiation data using empirical models and measurement techniques to optimize the orientation and tilt angles for maximum energy capture
2	Develop detailed designs of solar thermal systems, considering factors such as collector type, thermal storage, and heat transfer mechanisms and also evaluate their performance and efficiency metrics under varying environmental conditions
3	Analyze and optimize PV system performance characteristics for residential, commercial, and utility-scale applications
4	Apply knowledge of thermal and electrical energy storage technologies to integrate efficient energy storage solutions into solar energy systems.
5	Develop comprehensive strategies for the deployment of solar energy solutions in residential, commercial, and industrial sectors, considering economic viability, policy implications, and environmental sustainability

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	2	2	2	1	2	-	-	-	-	2	1	1
CO2	2	3	2	2	1	2	-	-	-	-	-	1	2
CO3	1	1	1	1	1	2	-	-	-	-	-	1	2
CO4	1	2	2	1	1	1	-	-	-	-	-	1	2
CO5	1	1	1	2	-	2	-	-	-	-	-	1	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. S. P. Sukhatme, J K. Nayak (2017), Solar Energy, 4th Edition – McGraw Hill Education

REFERENCE BOOKS:

1. John A.Duffie, William A.Beckman (2013), Solar Engineering of Thermal Processes, John Wiley & Sons.
2. Garg H P, Prakash J (2013), Solar Energy – Fundamentals and Applications, Tata McGraw Hill

E-Resources:

1. https://onlinecourses.nptel.ac.in/noc20_ph14/preview
2. https://archive.nptel.ac.in/courses/112/105/112105051/

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SUSTAINABLE PRACTICES FOR RURAL INDIA

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – V

Course Code	:	23ME3514	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the integration of AI and IoT in rural technologies.
2. Explore practical applications of these technologies in agriculture, healthcare, energy, rural small-scale industries, and education.
3. Evaluate the impact of AI and IoT on rural development through fieldwork and case studies.
4. Design and propose sustainable and scalable AI and IoT-based solutions for rural challenges.
5. Conduct detailed case studies of successful AI and IoT implementations in rural areas to understand best practices and success factors.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : Introduction to AI and IoT in Rural Contexts	**08 Hours**
Basics of AI and IoT: Overview of AI concepts and technologies, Fundamentals of IoT and its components. Challenges in Rural India: Key issues in rural development, Potential for AI and IoT interventions, **Current Applications:** Existing AI and IoT projects in rural India Case studies of successful implementations	

UNIT – II: AI and IoT in Agriculture	**08 Hours**
Precision Farming: AI-driven crop monitoring and management, IoT sensors for soil health and weather monitoring **Smart Irrigation Systems:** Automated irrigation using IoT, AI algorithms for water management **Agricultural Supply Chain:** AI in crop yield prediction and demand forecasting, IoT for real-time supply chain monitoring	

UNIT – III: AI and IoT in Healthcare	**08 Hours**
Remote Health Monitoring: IoT devices for vital signs monitoring, AI for predictive healthcare analytics, **Telemedicine Solutions:** Integrating AI in telehealth platforms, IoT-enabled mobile health units, **Public Health Management:** AI for disease outbreak prediction and control, IoT for improving sanitation and clean water access	
UNIT – IV: AI and IoT in Renewable Energy and Infrastructure	**08 Hours**
Smart Energy Solutions: IoT-based energy monitoring and management, AI for optimizing renewable energy systems, **Infrastructure Development:** IoT for smart grids and rural electrification, AI-driven infrastructure planning and maintenance, **Connectivity and Communication:** IoT solutions for rural connectivity, AI for optimizing communication networks	
UNIT – V: AI and IoT in Rural Small-Scale Industries	**07 Hours**
Automation and Efficiency: AI for process automation in small-scale industries, IoT for real-time monitoring and control, **Product Quality and Consistency:** AI for quality control and assurance, IoT for maintaining production standards **Market Access and Supply Chain:** AI for market analysis and demand forecasting, IoT for efficient supply chain and logistics management	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply AI and IoT concepts to address rural development challenges, analyze existing applications and successful case studies to implement AI-driven precision farming.
2	Design and implement IoT devices for remote health monitoring and mobile health units, integrate AI in telehealth platforms for predictive healthcare analytics.
3	Apply IoT-based energy monitoring and management systems, use AI to optimize renewable energy and infrastructure planning, and integrate IoT solutions for smart grids, rural electrification, and enhanced communication networks.
4	Apply AI and IoT technologies to automate processes in small-scale industries, ensure product quality and consistency, and enhance market access and supply chain management through real-time monitoring and demand forecasting.
5	Evaluate case studies of successful AI and IoT projects to identify best practices, and design and implement a pilot project based on fieldwork insights, assessing its impact and scalability.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	1	2	2	2	1	2	-	-	-	-	2	1	1
CO2	2	3	2	2	1	2	-	-	-	-	-	1	2
CO3	1	1	1	1	1	2	-	-	-	-	-	1	2
CO4	1	2	2	1	1	1	-	-	-	-	-	1	2
CO5	1	1	1	2	-	2	-	-	-	-	-	1	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks

1. Patel, K., & Patel, S. (2021). IoT and AI for Smart Agriculture. Springer.
2. Raj, P., & Raman, A. C. (2022). Innovations in Technologies for Rural Development. Cambridge University Press.

Reference Book:

1. Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2019). Internet of Things (IoT): Principles and Paradigms. Elsevier.
2. Liu, B., & Wang, Z. (2020). Artificial Intelligence in Agriculture. Elsevier.

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INNOVATION IN MANAGEMENT AND ENTREPRENEURSHIP

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23ME3601	**Credits**	:	02
Hours / Week	:	02 Hours	**Total Hours**	:	30 Hours
L–T–P–S	:	2–0–0–0			

Course Learning Objectives:

This course will enable students to:

1. Utilize management functions and planning steps to develop plans that achieve organizational goals. Students will practice applying these functions and steps in case studies and simulations to create effective organizational plans.
2. Describe how various organizational structures and staffing processes enhance operational efficiency. Students will explore different structures and staffing models, understanding their impact on efficiency through real-world examples.
3. Recall the principles of social responsibility and ethical practices in business. Students will list and memorize key principles, preparing them to recognize and discuss these concepts in business scenarios.
4. Explain how various strategies can enhance the performance and sustainability of small-scale industries. Through lectures and discussions, students will learn to articulate strategies that improve small-scale industry performance and sustainability.
5. Utilize project management tools and techniques to plan, execute, and evaluate successful projects. Students will engage in hands-on projects, using management tools to experience the full lifecycle of project management from planning to evaluation.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of material testing of different metals and alloys

UNIT – I Management and Planning	05 Hours
Management: Definition, Importance – Nature and Characteristics of Management, Management Functions, Roles of Manager, Levels of Management, Managerial Skills, Management & Administration, Management as a Science, Art &Profession. ***(Text Book-1: Chapter 1: 11 to 39).*** **Planning:** Nature, Importance and Purpose of Planning, Types of Plans, Steps in Planning, Limitations of Planning, Decision Making – Meaning, Types of Decisions- Steps in Decision Making. ***(Text Book-1: Chapter 2:69-125)***.	

UNIT – II: Organizing and Staffing	05Hours
Organizing and Staffing: Meaning, Nature and Characteristics of Organization – Process of Organization, Principles of Organization, Departmentalization, Committees – meaning, Types of Committees, Centralization Versus Decentralization of Authority and Responsibility, Span of Control (Definition only), Nature and Importance of Staffing, Process of Selection and Recruitment. ***(Text Book-1: Chapter 4: -195-235)***.	

UNIT – III: Social Responsibilities of Business:	06 Hours
Social Responsibilities of Business: Meaning of Social Responsibility, Social Responsibilities of Business towards Different Groups, Social Audit, Business Ethics and Corporate Governance. Entrepreneurship: Definition of Entrepreneur, Importance of Entrepreneurship, concepts of Entrepreneurship, Characteristics of successful Entrepreneur, Classification of Entrepreneurs, Intrapreneur – An Emerging Class, Comparison between Entrepreneur and Intrapreneur, Myths of Entrepreneurship, Entrepreneurial Development models, Entrepreneurial development cycle, Problems faced by Entrepreneurs and capacity building ***(Text Book-1: Chapter 4:-(235- 301)***.	

UNIT – IV: Modern Small Business Enterprises:	05 Hours
Modern Small Business Enterprises: Role of Small-Scale Industries, Concepts and definitions of SSI Enterprises, Government policy and development of the Small-Scale sector in India, Growth and Performance of Small-Scale Industries in India, Sickness in SSI sector, Problems for Small Scale Industries, Impact of Globalization on SSI, Impact of WTO/GATT on SSIs, Ancillary Industry and Tiny Industry (Definition only). **Institutional Support for Business Enterprises:** Introduction, Policies & Schemes of Central–Level Institutions, State-Level Institutions. ***(Text Book-2)***	

UNIT – V: Project Management:	05 Hours
Project Management: Meaning of Project, Project Objectives & Characteristics, Project Identification- Meaning & Importance; Project Life Cycle, Project Scheduling, Capital Budgeting, Generating an Investment Project Proposal, Project Report-Need and Significance of Report, Contents, Formulation, Project Analysis-Market, Technical, Financial, Economic, Ecological, Project Evaluation and Selection, Project Financing, Project Implementation Phase, Human & Administrative aspects of Project Management, Prerequisites for Successful Project Implementation. ***(Text Book-2)*** **New Control Techniques**- PERT and CPM, Steps involved in developing the network, Uses and Limitations of PERT and CPM. ***(Text Book-2)***	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply management principles to organize and lead teams effectively, making informed decisions and planning strategically to meet organizational goals.
2	Implement robust staffing and recruitment processes to build efficient organizational structures and enhance workforce capabilities.
3	Demonstrate a commitment to social responsibility and ethical practices in business, conducting social audits and promoting sustainable practices.
4	Analyze the impacts of globalization on small-scale industries and utilize institutional support to foster growth and mitigate challenges in the SSI sector.
5	Manage complex projects from inception to completion, using advanced techniques like PERT and CPM to optimize resources and achieve project objectives efficiently.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	2	2	2	1	2	-	-	-	-	2	1	1
CO2	2	3	2	2	1	2	-	-	-	-	-	1	2
CO3	1	1	1	1	1	2	-	-	-	-	-	1	2
CO4	1	2	2	1	1	1	-	-	-	-	-	1	2
CO5	1	1	1	2	-	2	-	-	-	-	-	1	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. Koontz, H., & Weihrich, H. (2020). Management: Principles and Applications (14th ed.). McGraw-Hill Education.
2. Gray, C. F., & Larson, E. W. (2018). Project Management: The Managerial Process (7th ed.). McGraw-Hill Education.

Reference Books:

1. Kotler, P., & Lee, N. (2005). Corporate Social Responsibility: Doing the Most Good for Your Company and Your Cause (1st ed.). Wiley.
2. Longenecker, J. G., Petty, J. W., Palich, L. E., & Hoy, F. (2019). Small Business Management: Launching & Growing Entrepreneurial Ventures (18th ed.). Cengage Learning.

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INTRODUCTION TO ADDITIVE MANUFACTURING
SEMESTER – VI

Course Code	:	23ME3602	**Credits**	:	03
Hours / Week	:	04 Hours	**Total Hours**	:	30+30 Hours
L–T–P–S	:	2–0–2–0			

Course Learning Objectives:

This course will enable students to:

1. Understand the fundamentals, classification, and advantages of Additive Manufacturing.
2. Explain the complete AM process chain from conceptualization to post-processing.
3. Compare various AM technologies based on principles, materials, and applications.
4. Apply Design for Additive Manufacturing (DFAM) principles for optimized part design.
5. Analyze industrial applications of AM across different sectors.
6. Perform AM operations including file preparation, machine setup, printing, and post-processing.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of different additive manufacturing methods

UNIT – I	05 Hours

INTRODUCTION:

Additive Manufacturing (AM) evolution, Distinction between AM & CNC machining, Advantages of AM; AM process chain: Conceptualization, CAD, conversion to STL, Transfer to AM, STL file manipulation, Machine setup, build, removal and clean up, post-processing; Classification of AM processes: Liquid polymer system, molten material systems, discrete particle system, solid sheet system.

UNIT – II	05 Hours
Liquid And Solid Based Additive Manufacturing Process: Stereolithography Apparatus (SLA): Principle, pre-build process, part-building and post-build processes, photopolymerization of SL resins, Advantages, limitations and applications; Solid Ground Curing (SGC): Principle, Process, Advantages, limitation, and applications; Fused deposition Modeling (FDM): Principle, details of processes Advantages, limitation, and applications; Laminated Object Manufacturing (LOM): Principles, details of processes, products, materials, advantages, limitations and applications.	
UNIT – III	**06 Hours**
Powder Based Additive Manufacturing Process Selective Laser Sintering (SLS): Principle, process, Indirect and direct SLS- powder structures, materials, post-processing, surface deviation and accuracy, Applications; Laser Engineered Net Shaping (LENS): Processes, materials, products, advantages, limitations and applications. Other Additive Manufacturing Systems: Shape Deposition Manufacturing (SDM), Ballastic Particle Manufacturing (BPM), Selective Laser Melting, Electron Beam Melting.	
UNIT – IV	**05 Hours**
Additive Manufacturing Applications Functional models, Pattern for investment and vacuum casting, Medical models, art models, Engineering analysis models, Rapid tooling (Direct and Indirect method), new materials development, Bi-metallic parts, and Re-manufacturing. Application examples for Aerospace, defense, automobile, Bio-medical and general engineering industries; Post-processing of AM parts: Support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using nonthermal and thermal techniques.	
UNIT – V	**05 Hours**
Design For Additive Manufacturing Motivation, DFMA concepts and objectives, AM unique capabilities, exploring design freedoms, Design tools for AM, Part Orientation, Removal of Supports, Hollowing out parts, Inclusion of Undercuts and Other Manufacturing Constraining Features, Interlocking Features, Reduction of Part Count in an Assembly, Identification of markings/ numbers etc.	

LAB COMPONENT

1. CAD Modeling and STL File Preparation: To design a 3D model, convert it into STL format, and analyze the file for Additive Manufacturing.
2. FDM Printing and Process Parameters, To study the FDM process, set up the machine, select parameters, and fabricate a physical part.
3. To perform SLA printing, including pre-processing, printing, and post-processing steps.
4. Powder-Based AM Process Simulation, to simulate powder-based AM processes and understand key process parameters.
5. Design for Additive Manufacturing (DFAM) Project, To apply DFAM principles in redesigning a component optimized for AM.
6. Demonstration of 3D printing of given polymer/metal/ceramic specimens

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

1	Analyze the principles, classifications, and differences between various Additive Manufacturing processes and conventional manufacturing methods.
2	Evaluate the suitability of different AM technologies for specific materials, applications, and industries based on technical and economic considerations.
3	Assess the complete AM process chain, including file preparation, machine setup, process parameters, and post-processing operations for quality improvement.
4	Design optimized components using Design for Additive Manufacturing (DFAM) principles, exploiting geometric freedom, part consolidation, and functional enhancements.
5	Design and execute complete AM manufacturing workflows by selecting suitable equipment, optimizing process parameters, and applying post-processing techniques to fabricate parts that meet specified functional and dimensional requirements.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	2	2	2	1	2	-	-	-	-	2	1	1
CO2	2	3	2	2	1	2	-	-	-	-	-	1	2
CO3	1	1	1	1	1	2	-	-	-	-	-	1	2
CO4	1	2	2	1	1	1	-	-	-	-	-	1	2
CO5	1	1	1	2	-	2	-	-	-	-	-	1	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

[1] Andreas Gebhardt and Jan-Steffen Hötter "Additive Manufacturing: 3D Printing for Prototyping and Manufacturing", Hanser publications, United States, 2015, ISBN: 978- 1 -56990-582-1.

[2] Ian Gibson, David W. Rosen and Brent Stucker "Additive Manufacturing Technologies: RapidPrototyping to Direct Digital Manufacturing", 2nd edition, Springer., United States, 2015, ISBN13: 978-1493921126.

REFERENCE BOOKS:

[1] Amit Bandyopadhyay and Susmita Bose, "Additive Manufacturing", 1st Edition, CRC Press., United States, 2015, ISBN-13: 978-1482223590.
[2] Andreas Gebhardt, "Understanding Additive Manufacturing: Rapid Prototyping, Rapid Manufacturing", Hanser Gardner Publication, Cincinnati., Ohio, 2011, ISBN:9783446425521.
[3] Kamrani A.K. and Nasr E.A., "Rapid Prototyping: Theory and Practice", Springer., United States, 2006, ISBN: 978-1 -4614-9842-1.
[4] Liou, L.W. and Liou, F.W., "Rapid Prototyping and Engineering Applications: A toolbox for prototype development", CRC Press., United States, 2011, ISBN: 9780849334092.
[5] Milan Brandt, "Laser Additive Manufacturing: Materials, Design, Technologies, and Applications", Woodhead Publishing., United Kingdom, 2016, ISBN: 9780081004333.

E-Resources:

- https://archive.nptel.ac.in/courses/112/103/112103306/
- https://onlinecourses.nptel.ac.in/noc22_me130/preview
- https://onlinecourses.nptel.ac.in/noc22_me122/preview

Activity-Based Learning (Suggested Activities in Class)

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NOISE, VIBRATION AND HARSHNESS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23ME3603	**Credits**	:	04
Hours / Week	:	05 Hours	**Total Hours**	:	45+30 Hours
L–T–P–S	:	3–0–2–0			

Course Learning Objectives:

This course will enable students to:

1. To understand the fundamentals of sound and its measurement.
2. To develop knowledge in finite element-based formulation for eigenvalue, frequency response, and transient dynamic problems.
3. To develop knowledge in modal and direct frequency response approaches used for the solution of vibration problems.
4. To learn applications of FEA and optimization to solve dynamic problems for vibration attenuation and noise reduction.
5. To identify dominant sources of noise and vibration in cars, their transmission paths, and their relative importance at different driving conditions.
6. To get an overview of state-of-the-art Computer Aided Engineering (CAE) applied to NVH and understand the limitations of these models.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- Practical experimentation

UNIT – I	08 Hours

FUNDAMENTALS OF SOUND:

Definition Of NVH, Vehicle Noise - Direct Sound Generation Mechanism: Airborne Sound; Indirect Sound Generation Mechanism: Structure Borne Sound; Subjective Response Sound, Acoustic Variables, Basic Attributes Of Sound Such As Wavelength, Period, Frequency; Speed Of Sound, Decibel Scale, Wave Equation, Types Of Sound Fields, Measures Of Sound: Sound

Pressure, Sound Intensity And Sound Power, Combining Sources: dB Arithmetic, Standing Wave, Beating, Impedance, Human Hearing: Frequency Versus Sound Pressure Level, Loudness: Phons And Sones As Noise Descriptors; Weighting Networks, Leqand Various Noise Metrics For Road Noises.

UNIT – II	8 Hours

FINITE ELEMENT FORMULATION FOR 1D AND 2D EIGENVALUE PROBLEM

Introduction To Hamilton's Principle; Principle Of Minimum Potential Energy; Stresses And Equilibrium; Strain Displacement Relationship; Stress Strain Relationship ; Special Cases – 1D And 2D Problems; Natural Coordinate System; Element And Global Stiffness & Mass Matrix For 1D & 2D Spring, Truss, Beam Elements, 2D CST Element, Quadrilateral Element; Element And Global Stiffness & Mass Matrix For 1D & 2D Spring, Truss, Beam Elements, 2D CST Element, Quadrilateral Element; Harmonic Loads- Wheel Unbalance, Speed Breakers, Harmonic Loads- Wheel Unbalance, Speed Brakers, And Engine Unbalance; Real Eigenvalue Problem Formulation; Orthogonal Properties Of Eigenvectors; Raleigh Quotient; Generalized Mass, Stiffness And Force Vector; Consistent Mass Matrix And Lump Mass Matrix; Rigid Body Modes

UNIT – III	08 Hours

DAMPING & FORCED HARMONIC AND TRANSIENT DYNAMIC RESPONSE ANALYSES

Modal Damping, Raleigh Damping, Structural Damping; Mathematical Modeling of Elastomers with Static and Dynamic Stiffness with Frequency Dependent Characteristics;
Mode Superposition Method and Direct Method for Solution of Forced Harmonic and Transient Dynamic Analyses; Physical Verses Modal Coordinates; Modal Mass, Modal Stiffness, & Modal Force; Cut-Off Frequency for Solution of Low Frequency NVH Problems; Nyquist Rule

UNIT – IV	08 Hours

SOURCES OF VEHICLE VIBRATION:

Power Train And Engine Vibrations; Driveline Vibrations; Chassis and Suspension Vibrations; Control Strategies; Human Response to Vehicle Vibrations, Concept of Harshness; Subjective and Objective Evaluation of Vehicle Harshness.
Vibration Isolation and Control:
Introduction; Damping of Vibrations; Vibration Isolation and Absorption; Design of A Vibration Absorbers, Unconstrained and Constrained Layer Damping Treatment, Add On Dampers and Stiffeners, Introduction To Active Vibration Control.

UNIT – V	07 Hours

ADVANCED TOPICS IN FINITE ELEMENT BASED NVH OPTIMIZATION

Modal Alignment; Point Mobility Analysis; Transfer Function Analysis; Vibroacoustic - Applications of Fluid-Structure Interaction to Predict Noise and Vibration Using Finite Element Software; Applications of Topology and Sizing Optimization for Automotive Problems.

LAB COMPONENT

1. Modal Analysis of a Cantilever Beam Using FEA
2. Extract natural frequencies and mode shapes using finite element software.
3. Harmonic Response Analysis of a Beam or Plate
4. Study the steady-state forced vibration response under harmonic loading.
5. Transient Dynamic Analysis of a Suspension System
6. Simulate the transient vibration response of a simplified vehicle suspension to road inputs.
7. Vibration Isolation Analysis using Elastomer Mount (FEA Simulation)

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Apply the fundamentals of sound, vibration, and noise measurement to analyze NVH issues in mechanical systems.	L3
2	Analyze dynamic problems using finite element-based formulations for modal, harmonic, and transient responses.	L4
3	Apply damping techniques and vibration isolation methods to control noise and vibration.	L3
4	Evaluate NVH characteristics of automotive sub-systems using simulation tools and experimental data.	L3
5	Design optimization solutions for noise and vibration reduction using advanced finite element methods.	L3

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	2	2	2	2	2	-	-	-	-	-	-	2	1
CO2	2	2	2	2	3	-	-	-	-	-	-	2	1
CO3	1	2	2	3	2	-	-	-	-	-	-	2	1
CO4	1	1	1	1	3	-	-	-	-	-	-	2	1
CO5	1	1	3	1	1	-	-	-	-	-	-	2	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Finite element analysis, P. Sheshu, PHI Learning Pvt. Ltd., New Delhi
2. Kinsler, L.E., Frey, A.R., Coppens, A.B. and Sanders, J.V., 2000. Fundamentals of acoustics. John wiley & sons.
3. Mathew Harrison Vehicle Refinement- Controlling Noise & Vibration in Road Vehicles, Elsevier Publication(2004).
4. Introduction to optimal design, J.S. Arora, 4th edition, Elsevier Science Publishing Co. Inc

REFERENCES:

1. Theory and Problems of Mechanical Vibrations - William W. Seto, McGraw Hill International BookCo., Singapore (Schaum's outline series)
2. Mechanical Vibrations - S. S. Rao, Pearson Education Inc.,
3. Mechanical Vibrations - S. Graham Kelly, Schaum's Outline Series, Tata McGraw Hill Publishing Co.Ltd., New Delhi.
4. Finite element procedures, K.J. Bathe, Prentice-Hall

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QUALITY AND RELIABILITY

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23ME3604	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This course will enable students to:

1. Understand the principles of quality control, quality assurance, and reliability.
2. Apply statistical tools for quality control and process capability analysis.
3. Analyze failure data to assess system reliability and maintainability.
4. Understand design for quality, six sigma, and continuous improvement frameworks.
5. Develop skills for implementing quality management systems and reliability-centered maintenance.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.

UNIT – I	**08 Hours**

QUALITY CONCEPTS AND STANDARDS

Definitions: Quality, Quality Control, Quality Assurance, Total Quality Management (TQM). Cost of Quality (CoQ). Quality Gurus: Deming, Juran, Crosby, Taguchi. ISO 9000 Standards, QS-9000, IATF 16949, ISO 14001, ISO 45001. Malcolm Baldrige National Quality Award (MBNQA).

UNIT – II	**8 Hours**

STATISTICAL QUALITY CONTROL (SQC)

Process Variation, Control Charts: X-bar, R, p, np, c, u charts. Acceptance Sampling Plans: Single, Double, Multiple Sampling. Operating Characteristic (OC) curves. Process Capability Indices: Cp, Cpk, Pp, Ppk.Measurement System Analysis (MSA).

UNIT – III	08 Hours
RELIABILITY ENGINEERING BASICS Reliability Definitions and Concepts. Failure Patterns: Bathtub Curve. Failure Rate, Mean Time To Failure (MTTF), Mean Time Between Failures (MTBF). Reliability Functions, Hazard Rate. Reliability of Series, Parallel, and Redundant Systems.	
UNIT – IV	**08 Hours**
FAILURE MODE ANALYSIS AND MAINTAINABILITY Failure Modes and Effects Analysis (FMEA). Fault Tree Analysis (FTA). Reliability-Centered Maintenance (RCM). Maintainability and Availability. Preventive, Predictive & Condition-Based Maintenance.	
UNIT – V	**07 Hours**
QUALITY IMPROVEMENT TECHNIQUES Six Sigma Methodology: DMAIC approach. Taguchi Methods: Design of Experiments (DOE). Kaizen, 5S, Poka-Yoke. Continuous Improvement Tools. Benchmarking and Best Practices.	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Apply fundamental concepts of quality management, quality assurance, and control tools in manufacturing systems.	L3
2	Analyze process capability, control charts, and statistical process control methods.	L4
3	Apply reliability engineering techniques to predict product/service performance and failure rates.	L3
4	Evaluate maintainability, availability, and failure modes using system reliability models.	L3
5	Design quality improvement strategies using six sigma, TQM, and continuous improvement principles.	L3

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	1	2	1	1	-	-	-	-	-	-	2	1
CO2	1	1	1	1	1	-	-	-	-	-	-	2	1
CO3	1	1	1	1	1	-	-	-	-	-	-	2	1
CO4	1	1	1	1	1	-	-	-	-	-	-	2	1
CO5	2	2	3	2	2	-	-	-	-	-	-	2	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Text Books

1. Douglas C. Montgomery, *Introduction to Statistical Quality Control*, Wiley.
2. E. E. Lewis, *Introduction to Reliability Engineering*, Wiley.
3. Amitava Mitra, *Fundamentals of Quality Control and Improvement*, Wiley.
4. Dale H. Besterfield, *Quality Control*, Pearson Education.

Reference Books

1. Frank Gryna & Joseph Juran, *Quality Planning and Analysis*, McGraw Hill.
2. B.S. Dhillon, *Engineering Maintainability*, Prentice Hall.

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OPEN ELECTIVES-1

SUSTAINABLE ENGINEERING					
Course Code	:	23OE0034	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:
This course will enable students to:

1. Introduce the foundational concepts of sustainable engineering and its role in addressing environmental and resource challenges.
2. Develop the ability to analyze energy and material flows in engineering systems and propose efficient conservation strategies.
3. Apply green design and sustainable manufacturing principles for minimizing environmental impacts across product life cycles.
4. Integrate sustainable approaches in mobility, infrastructure, and construction while balancing performance, safety, and environmental considerations.
5. Utilize digital tools, lifecycle assessment, and responsible innovation frameworks in making ethical and sustainable engineering decisions

Teaching-Learning Process (General Instructions)
These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of different additive manufacturing methods

UNIT – I	08 Hours
Foundations of Sustainable Engineering Sustainability principles in engineering systems, environmental and resource challenges. Systems thinking in design and analysis, lifecycle perspective, and circular economy concepts. Product stewardship and sustainable development goals as guiding frameworks. Understanding the role of engineers in sustainable transitions across	

sectors.

UNIT – II	08Hours
Energy and Resource Efficiency Energy flow in thermal, fluid, and structural systems, identifying loss points. Energy conservation strategies and efficient design practices in physical systems. Material efficiency, sustainable sourcing, and reduction of embodied energy. Case studies on optimizing system performance for minimal resource use.	

UNIT – III	06 Hours
Green Design and Manufacturing Design for environment (DfE), reuse, and ease of disassembly in product lifecycle. Sustainable manufacturing through low-emission machining and fabrication methods. Additive and subtractive processes with minimal material waste. Selection of processes and materials based on environmental performance.	

UNIT – IV	08 Hours
Sustainable Mobility and Infrastructure Light weighting and material substitution in transportation system design. Structural optimization for energy savings and enhanced durability. Sustainable material choices in public infrastructure and construction. Balancing safety, performance, and environmental considerations in design.	

UNIT – V	09 Hours
Digital Tools and Responsible Innovation Lifecycle Assessment (LCA) using digital tools for evaluating sustainability. Design optimization and predictive analytics for efficient system operation.AI-assisted support in material selection and maintenance planning. Engineering ethics, standards, and compliance with EPR, RoHS, and SDGs.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Analyze engineering systems from a sustainability perspective and evaluate lifecycle and circular economy principles for improved system design.
2	Assess energy flows and material usage in complex engineering systems to propose efficient conservation and resource optimization solutions.
3	Design products and manufacturing processes that minimize emissions, waste, and environmental impact throughout the product lifecycle.
4	Evaluate sustainable mobility and infrastructure solutions by integrating material selection, structural optimization, and durability considerations.
5	Apply digital tools, lifecycle assessments, and AI-supported methods to optimize system performance while ensuring compliance with ethical standards and sustainability regulations.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	2	1	2	1	1	1	1	-	-	-	1	2	1
CO2	1	1	1	1	1	1	1	-	-	-	1	2	1
CO3	1	1	3	1	1	2	1	-	-	-	1	2	1
CO4	1	1	1	1	1	2	1	-	-	-	1	2	1
CO5	2	2	3	2	2	1	1	-	-	-	1	2	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS :

1. David T. Allen, David R. Shonnard, *Sustainable Engineering: Concepts, Design and Case Studies*, 2nd Edition, Pearson Education, 2012.
2. Bhavik R. Bakshi, *Sustainable Engineering: Principles and Practice*, Cambridge University Press, 2019.

REFERENCES :

1. David Dornfeld (Ed.), *Green Manufacturing: Fundamentals and Applications*, Springer, 2013.
2. Michael F. Ashby, *Materials and the Environment: Eco-Informed Material Choice*, 2nd Edition, Elsevier, 2012.

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MATERIALS FOR ENGINEERING APPLICATIONS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23OE0035	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the basic classification and properties of engineering materials including metals, ceramics, polymers, and composites.
2. Gain proficiency in testing and characterizing material properties such as tensile strength, thermal conductivity, and electrical resistivity.
3. Acquire knowledge of materials suitable for high-temperature applications and their roles in industries like aerospace and power generation.
4. Learn the criteria for selecting materials for electronics and computing, including conductors, insulators, and semiconductor materials.
5. Explore the composition, advantages, and manufacturing processes of composite materials and their applications across various sectors.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : INTRODUCTION TO ENGINEERING MATERIALS	**06 Hours**
An overview of the significance of materials in engineering, Classification of engineering materials based on their properties, such as metals, polymers, ceramics, and composites. Material properties and their importance in engineering design and applications.	
UNIT – II: MATERIAL PROPERTIES AND TESTING	**09 Hours**
Mechanical properties, including tensile strength, hardness, elasticity. Thermal properties, such as thermal conductivity and coefficient of thermal expansion. Electrical properties, including electrical conductivity and resistivity.	

UNIT – III: MATERIALS FOR HIGH-TEMPERATURE APPLICATIONS	09 Hours
High-temperature materials are essential in various engineering fields. This module focuses on: Materials that exhibit resistance to high temperatures, including refractory materials and super alloys. Applications of high-temperature materials in industries such as aerospace, power generation, and metallurgy. Thermal management materials used to dissipate heat effectively in electronic devices and other applications.	
UNIT – IV: MATERIALS FOR ELECTRONICS AND COMPUTING	**07 Hours**
Conducting materials, such as metals and semiconductors, used in electronic circuits. Insulating materials to isolate and protect electronic components. Materials for electronic components, including resistors, capacitors, and semiconductors. Real-world case studies highlighting materials used in microprocessors and memory devices.	
UNIT – V: COMPOSITE MATERIALS	**08 Hours**
The concept of composite materials and their composition. Advantages and disadvantages of composites. Applications of composites in various industries, including aerospace, automotive, and sports equipment. An overview of manufacturing processes for composites, including layup techniques and curing methods.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	**Differentiate** engineering materials by their properties, including metals, polymers, ceramics, and composites.
2	**Evaluate** mechanical and thermal properties of materials through standardized testing, determining suitability for applications.
3	**Analyze** high-temperature materials for their performance in aerospace and power generation applications and industries.
4	**Examine** conducting and insulating materials in electronics to assess their roles in circuit design and functionality.
5	**Interpret** composite materials composition and applications, evaluating their advantages and manufacturing processes in industry contexts.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	2	-	-	1	-	-	-	-	-	-	2
CO2	3	2	2	-	-	-	-	-	-	-	-	-	2
CO3	3	2	2	2	-	1	-	-	-	-	-	-	2
CO4	3	2	2	2	-	1	-	-	2	-	-	2	2
CO5	3	2	2	2	-	1	-	3	3	-	-	2	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. Callister, W. D., Jr., & Rethwisch, D. G. (2020). Materials Science and Engineering: An Introduction (10th ed.). Wiley.
2. Budinski, K. G., & Budinski, M. K. (2012). Engineering Materials: Properties and Selection (9th ed.). Prentice Hall.

Reference Books:

1. Ashby, M. F. (2017). Materials Selection in Mechanical Design (5th ed.). Butterworth-Heinemann.
2. Callister, W. D., Jr., & Rethwisch, D. G. (2020). Fundamentals of Materials Science and Engineering: An Integrated Approach (5th ed.). Wiley.

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OPERATIONS RESEARCH
[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23OE0036	**Credits**	:	03
Hours / Week	:	04 Hours	**Total Hours**	:	45
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:
This course will enable students to:

1. Understand and formulate linear programming problems and apply solution techniques such as graphical and simplex methods.
2. Analyze and solve transportation, assignment, and sequencing problems using various optimization methods.
3. Explore inventory control models under deterministic and probabilistic demands for effective resource management.
4. Study queuing theory models and apply simulation techniques for analyzing service systems.
5. Apply game theory and replacement models for decision-making in competitive and operational environments.

Teaching-Learning Process (General Instructions)
These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of different additive manufacturing methods

UNIT – I	**08 Hours**

Linear Programming Problem:
Introduction to Operations Research – Linear Programming - Mathematical Formulation – Graphical method – Simplex method – Penalty methods: M-method, Two Phase method-

Duality.

UNIT – II	08Hours
Transportation, Assignment and Sequencing Problem Introduction - Formulation - Solution of the transportation problem (Min and Max): Northwest Corner rule, row minima method, column minima method, Least cost method, Vogel's approximation method – Optimality test: MODI method. Assignment problems – Applications - Minimization and Maximization; Sequencing - Problem with N jobs and 2 machines – n jobs and 3 machines problem - n jobs and m machines problem.	

UNIT – III	06 Hours
Inventory Control : Necessity for maintaining inventory - Inventory costs -Inventory models with deterministic demand - inventory models with probabilistic demand - Inventory models with price breaks - Buffer stock.	

UNIT – IV	08 Hours
Queuing Models: Poisson arrivals and Exponential service times – Single channel models and Multi-channel models - Simulation: Basic concepts, Advantages and disadvantages - Random number generation - Monte Carlo Simulation applied to queuing problems.	

UNIT – V	09 Hours
Game theory and Replacement Models: Game theory: Competitive games - Useful terminology - Rules for game theory - Two person zero sum game – Property of dominance - Graphic solution – Algebraic method. Replacement models: Replacement of items that deteriorate with time: No changes in the value of money, changes in the value of money - Items that fail completely: Individual replacement and group replacement policies.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Analyze real-world problems to formulate appropriate linear programming models and select suitable optimization methods for their solutions.
2	Evaluate and compare different solution approaches in transportation and assignment problems to determine the most cost-effective strategies.
3	Design customized inventory control systems considering various demand scenarios and cost factors for efficient stock management
4	Assess queuing models and simulation results to recommend improvements in service operations and resource allocation.
5	Develop optimal strategies using game theory and replacement models to solve complex decision-making problems in industrial operations.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	1	2	1	1	-	-	-	-	-	-	2	1
CO2	1	1	1	1	1	-	-	-	-	-	-	2	1
CO3	1	1	1	1	1	-	-	-	-	-	-	2	1
CO4	1	1	1	1	1	-	-	-	-	-	-	2	1
CO5	2	2	3	2	2	-	-	-	-	-	-	2	1

TEXT BOOKS :

1. Hamdy A Taha, Operations Research: An Introduction, 9th edition, Pearson Education, Inc., 2014
2. Frederick S. Hillier, Gerald J. Lieberman, Introduction to Operations Research, 10th Edition, McGraw Hill Education, 2015.

REFERENCES :

1. Kanti Swarup, P.K. Gupta, Man Mohan, *Operations Research*, 18th Edition, Sultan Chand & Sons, 2015.
2. J. K. Sharma, *Operations Research: Theory and Applications*, 5th Edition, Macmillan India, 2013.
3. H.M. Wagner, *Principles of Operations Research*, 2nd Edition, Prentice Hall of India, 1994.

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INDUSTRIAL ROBOTICS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23OE0037	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the fundamental principles, components, and classifications of industrial robots and their applications in various industries.
2. Develop the ability to analyze robot kinematics and dynamics for designing and optimizing robotic movements and tasks.
3. Acquire skills in programming industrial robots using various control strategies and understanding the integration of sensors and feedback mechanisms.
4. Apply knowledge of robotics to real-world industrial applications, focusing on automation in manufacturing and exploring robotics in non-traditional sectors.
5. Explore future trends in robotics, including the use of collaborative robots and the integration of artificial intelligence, to stay abreast of technological advancements.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : Introduction to Industrial Robotics	**06 Hours**
Overview of Industrial Robotics: History, evolution, and current trends in robotic technology. Types of Robots: Differentiate between articulated, SCARA, delta, and Cartesian robots based on structure and application areas. Robot Components: Detailed study of robot components including actuators, sensors, end-effectors, and controllers.	

UNIT – II: Robot Kinematics and Dynamics	**10 Hours**
Fundamentals of Kinematics: Introduction to kinematic chains, degrees of freedom, and robot motion analysis. Forward and Inverse Kinematics: Mathematical modeling to describe robot positions and orientations. Robot Dynamics: Understanding the forces and torques acting on robotic systems during movement.	

UNIT – III: Robot Control Systems	10 Hours
Control Strategies: Overview of point-to-point control, continuous path control, and adaptive control. Programming Robots: Introduction to robot programming languages and offline programming techniques. Sensors and Feedback: Role of sensors in robotics, sensor types, and their applications for feedback in robotic systems.	

UNIT – IV: Applications of Industrial Robots	07 Hours
Robot Applications in Manufacturing: Automation of welding, assembly, painting, and material handling. Advanced Applications: Introduction to robots in non-manufacturing sectors such as healthcare, military, and service industries. Safety and Ergonomics: Understanding the safety protocols and human-robot interaction considerations in industrial settings.	
UNIT – V: Future Trends and Innovations in Robotics	**08 Hours**
Collaborative Robots (Cobots): Exploring the capabilities and applications of cobots in industrial environments. Integration of AI and Machine Learning: How AI is being integrated into robotic systems to enhance functionality and decision-making. Sustainability and Robotics: Discussion on the environmental impact of robotics and sustainable practices in robot design and deployment.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Analyze the history, evolution, and current trends in robotic technology to assess their impact on industrial automation practices.
2	Apply kinematic chains and degrees of freedom, construct and evaluate forward and inverse kinematics models, and analyze forces and torques to design and optimize robotic systems.
3	Evaluate control strategies, develop robot programming using various languages and offline techniques, and integrate sensors for feedback to design and optimize robotic control systems.
4	Design robot applications in manufacturing, develop advanced applications in non-manufacturing sectors, and integrate safety protocols and ergonomics to evaluate and optimize industrial robotic systems.
5	Evaluate and integrate AI and machine learning to enhance robotic functionality and sustainability practices to innovate and optimize future trends in robotics.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	1	2	1	1	-	-	-	-	-	-	2	1
CO2	1	1	1	1	1	-	-	-	-	-	-	2	1
CO3	1	1	1	1	1	-	-	-	-	-	-	2	1
CO4	1	1	1	1	1	-	-	-	-	-	-	2	1
CO5	2	2	3	2	2	-	-	-	-	-	-	2	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. Craig, J. J. (2017). *Introduction to Robotics: Mechanics and Control* (4th ed.). Pearson.
2. Mittal, R. K., & Nagrath, I. J. (2003). *Robotics and Control*. Tata McGraw-Hill Education.

Reference Books:

1. Janakiraman, P. A. (2009). *Robotics (Industrial Robotics)* (1st ed.). PHI Learning Pvt. Ltd.
2. Siciliano, B., & Khatib, O. (Eds.). (2016). *Handbook of Robotics* (2nd ed.). Springer.

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PROFESSIONAL ELECTIVE II

Drives & Control systems

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23ME3606	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the fundamental principles and applications of various mechanical and electrical drive systems used in mechanical engineering.
2. Gain knowledge of power electronics including converters, inverters, and their role in drive systems.
3. Acquire skills in selecting and applying appropriate motor control techniques for different types of motors used in mechanical systems.
4. Learn to integrate hydraulic, pneumatic, and electrical control systems into mechanical designs for enhanced functionality.
5. Explore advanced control strategies and the latest technologies in drive systems to prepare for future challenges in mechanical engineering.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : Introduction to Drive Systems	09 Hours
Overview of Drive Systems: Role and types of drives in mechanical systems. Mechanical Drives: Study of belt, chain, and gear drives, focusing on their characteristics, applications, and selection criteria. Electrical Drives: Basics of electrical drive systems, including AC and DC drives,	

UNIT – II: Power Electronics in Drive Systems	09 Hours
Introduction to Power Electronics: Role of power electronics in controlling and driving mechanical systems. Semiconductor Devices: Thyristors, TRIACs, DIACs, and power transistors. Converters and Inverters: Basic circuits and their applications in drive systems, focusing on voltage and current control.	
UNIT – III: Electric Motor Control	**06 Hours**
Types of Motors: Induction, stepper, servo, and DC motors. Motor Starting Methods: Direct-on-line, star-delta, autotransformer, and electronic starters. Speed Control Methods: Various techniques for controlling motor speed, vector control and direct torque control.	
UNIT – IV: Control Systems for Mechanical Applications	**07 Hours**
Hydraulic and Pneumatic Control Systems: Components, circuit design, and applications. Control Strategies: Introduction to adaptive control, robust control, and predictive control. System Integration: Integrating control systems with mechanical components to create efficient, responsive mechanical systems.	
UNIT – V: Advanced Topics and Emerging Technologies	**08 Hours**
Regenerative and Energy Efficient Drives: Techniques and importance of energy efficiency in drive systems. Wireless and Remote Control of Drives: Technologies and applications in modern industry. Case Studies and Applications: Real-world applications and case studies focusing on innovative uses of drives and control systems in mechanical engineering.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply theoretical knowledge of different drive systems to evaluate and select suitable mechanisms for specific mechanical engineering applications.
2	Design and analyze power electronic circuits used in drive systems to meet specified performance and efficiency criteria.
3	Apply advanced motor control techniques for various types of electric motors, optimizing for performance and energy efficiency.
4	Apply diverse control systems, including hydraulic and pneumatic, to develop comprehensive mechanical system designs.
5	Evaluate and adapt emerging drive technologies and control strategies critically to innovate and resolve practical mechanical engineering challenges.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	1	2	1	1	-	-	-	-	-	-	2	1
CO2	1	1	1	1	1	-	-	-	-	-	-	2	1
CO3	1	1	1	1	1	-	-	-	-	-	-	2	1
CO4	1	1	1	1	1	-	-	-	-	-	-	2	1
CO5	2	2	3	2	2	-	-	-	-	-	-	2	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. Hughes, A., & Drury, B. (2013). Electric Motors and Drives: Fundamentals, Types, and Applications (4th ed.). Elsevier.
2. Mohan, N., Undeland, T. M., & Robbins, W. P. (2003). Power Electronics: Converters, Applications, and Design (3rd ed.). Wiley.

Reference Books:

1. Sen, P. C. (2014). Principles of Electric Machines and Power Electronics (3rd ed.). Wiley.
2. Dorf, R. C., & Bishop, R. H. (2016). Modern Control Systems (13th ed.). Pearson.

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MATERIALS FOR ADDITIVE MANUFACTURING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	: 23ME3607	**Credits**	: 03
Hours / Week	: 03 Hours	**Total Hours**	: 45 Hours
L–T–P–S	: 3–0–0–0		

Course Learning Objectives:

This Course will enable students to:

1. Understand the role and selection of various materials used in additive manufacturing.
2. Explore design and quality aspects related to additive manufacturing, including intellectual property and commercialization.
3. Study mathematical models and decision methods for optimizing additive manufacturing processes.
4. Investigate the applications of additive manufacturing in biomedical devices and other industries.
5. Learn advanced techniques and advancements in rapid manufacturing for polymeric, metallic, and ceramic objects.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : ROLE OF MATERIALS	**09 Hours**
Choosing Materials for Manufacturing, Multiple Materials, Metal AM Processes & Materials Composite Materials, Biomaterials, Heirarchical Materials & Bio mimetics, Ceramics & Bio-ceramics, Shape-Memory Materials, 4D Printing & Bio-active materials, Discussion on different materials used, multifunctional and graded materials in AM	
UNIT – II: Power Electronics in Drive Systems	**06 Hours**

Machines for Additive Manufacturing, Secondary Rapid Prototyping processes, Intellectual Property, Product Development, Commercialization, Trends and Future Directions in Additive Manufacturing. Design for AM (Build orientation, Topology optimization, Conformal cooling channels).

UNIT – III: MATHEMATICAL MODELS IN AM	09Hours
Selection of AM technologies using decision methods, AM process plan, Monitoring and control of defects, transformation. Case studies: Numerical Modeling of AM process, Powder bed melting based process, Droplet based printing process, Residual stress, part fabrication time, cost, optimal orientation and optimal Defect in AM and role of transport Simulations (choice of parameter, Model validation for different criteria). Thermal cycle, Single bead and multi bead formation in cladding-based AM processes	
UNIT – IV: ADDITIVE MANUFACTURING FOR BIO MEDICAL DEVICES & OTHERS	09 Hours
Bio microfluidics, Tissue Engineering. 3D Printing in Medicine, Computer Aided Design approach, medical research and clinical grade AM materials and AM fabrication methods Biomedical Applications, Direct Digital Manufacturing, Distributed Manufacturing, Mass Customization, Aerospace & Automotive Applications, Architectural Engineering, Food & Consumer Applications, Personalized Surgery, Art, Fashion, Jewelry, Toys & Other Applications	
UNIT – V: RAPID MANUFACTURING OBJECTS	06 Hours
RM of polymeric objects, Direct and indirect routes for RM of metallic & ceramic objects, Advancement in RM (Synergistic integration of hybrid processes and multiple technologies). Smart materials.	

Course Outcome	Description
1	Differentiate various materials used in additive manufacturing, including metals, composites, and biomaterials.
2	Analyze power electronics in drive systems and their impact on additive manufacturing processes.
3	Evaluate mathematical models in additive manufacturing for defect monitoring and process optimization.
4	Examine the applications of additive manufacturing in biomedical devices and personalized solutions.
5	Interpret rapid manufacturing techniques for polymeric and metallic objects, assessing advancements and smart materials.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	2	2	2	-	-	-	-	-	-	-	-	-	3
CO3	2	3	2	2	2	-	-	-	-	-	-	-	3
CO4	2	3	3	2	-	-	-	-	-	-	-	-	3
CO5	2	2	3	2	-	-	-	-	-	-	-	-	3

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. Gibson, I., Rosen, D., & Stucker, B. (2020). Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing. Springer.
2. Zhou, K., & Wang, C. (2021). Additive Manufacturing: Materials, Processes, Quantifications and Applications. Elsevier.

Reference Books:

1. Srivatsan, T. S., & Sudarshan, T. S. (2015). Additive Manufacturing: Innovations, Advances, and Applications. CRC Press.
2. Chua, C. K., & Leong, K. F. (2017). 3D Printing and Additive Manufacturing: Principles and Applications (5th ed.). World Scientific.

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AUTOTRONICS
[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code :	23ME3608	**Credits**	**:** 03
Hours/Week :	03 Hours	**Total Hours**	**:** 45Hours
L–T–P–S :	3-0-0-0		

Course Learning Objectives:

This course will enable students to:

1. Understand the significance of autotronics in modern vehicles.
2. Learn the basics of automotive electronics, sensors, and ECUs.
3. Master automotive communication systems and diagnostic protocols.
4. Gain expertise in engine management and advanced driver-assistance systems.
5. Explore hybrid and electric vehicle technologies, and future trends in automotive electronics

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of material testing of different metals and alloys

Unit-1: Introduction to Autotronics	**8 Hours**
Overview of Autotronics and its significance in modern vehicles. Basic electronics and electrical systems in automobiles. Sensors and actuators: Types, working principles, and applications. Electronic control units (ECUs): Functionality and architecture.	

Unit-2: Automotive Communication Systems	**8 Hours**
In-vehicle networking: CAN, LIN, MOST, and FlexRay protocols. Data transmission and communication standards in automobiles. Diagnostics and On-Board Diagnostics (OBD) systems Real-time operating systems and software for automotive applications.	
Unit-3: Engine Management Systems	**8 Hours**
Electronic Fuel Injection (EFI) systems: Components and operation. Ignition systems: Types, working principles, and control strategies. Exhaust gas recirculation and emission control technologies. Advanced driver-assistance systems (ADAS): Functions and integration.	
Unit-4: Hybrid and Electric Vehicle Technology:	**8 Hours**
Basics of hybrid and electric powertrains. Battery management systems: Monitoring, control, and safety. Regenerative braking systems and energy recovery. Power electronics in hybrid and electric vehicles: Inverters, converters, and controllers.	
Unit-5: Advanced Topics in Autotronics:	**7 Hours**
Autonomous vehicles: Sensors, algorithms, and control systems. Vehicle-to-everything (V2X) communication and connectivity. Advanced safety systems: Collision avoidance, adaptive cruise control, and lane-keeping assistance. Future trends in automotive electronics: AI and machine learning in vehicles.	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Analyze and evaluate the functionality and architecture of Electronic Control Units (ECUs) within modern automotive systems to optimize vehicle performance.
2	Assess and implement automotive communication protocols such as CAN, LIN, MOST, and Flex Ray to enhance in-vehicle networking and diagnostic capabilities.
3	Design and manage advanced engine management systems, including Electronic Fuel Injection (EFI) and ignition control strategies, to improve fuel efficiency and emission control.
4	Develop and integrate hybrid and electric vehicle technologies, focusing on battery management systems, regenerative braking, and power electronics to enhance vehicle sustainability and performance.
5	Investigate and apply advanced topics in autotronics such as autonomous vehicle technologies, V2X communication, and AI-driven safety systems to advance future automotive innovations.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)										PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	1	2	1	1	-	-	-	-	-	-	2	1

CO2	1	1	1	1	1	-	-	-	-	-	-	2	1
CO3	1	1	1	1	1	-	-	-	-	-	-	2	1
CO4	1	1	1	1	1	-	-	-	-	-	-	2	1
CO5	2	2	3	2	2	-	-	-	-	-	-	2	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. Navet, N., & Simonot-Lion, F. (2017). Automotive Embedded Systems Handbook. CRC Press.
2. Ribbens, W. (2017). Understanding Automotive Electronics. Elsevier.

Reference Books:

1. Reif, K. (2014). Automotive Mechatronics: Automotive Networking, Driving Stability Systems, Electronics. Springer.
2. Mi, C., Masrur, M. A., & Gao, D. W. (2017). Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives. Wiley.

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WIND ENERGY SYSTEMS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23ME3609	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Comprehend the basic principles of wind energy conversion and the components of wind turbines
2. Optimize blade designs and understand advanced aerodynamic effects on turbine efficiency
3. Understand the dynamic loads and structural behavior of wind turbines
4. Implement control systems to enhance wind turbine performance and grid stability
5. Explore the unique challenges of offshore wind energy systems, including design and maintenance.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.
-

UNIT – I : FUNDAMENTALS OF WIND ENERGY AND RESOURCE	**07 Hours**

Overview of wind energy as a renewable resource. Historical development and current trends in wind energy. Basic components and functioning of wind turbines.
Wind characteristics: speed, direction, and variability. Methods for measuring and estimating wind resources. Criteria for selecting wind farm sites and optimizing layout.

UNIT – II: WIND TURBINE AERODYNAMICS AND PERFORMANCE:	**08 Hours**

Airfoil characteristics and aerodynamic forces, Blade Element Momentum (BEM) theory. Power coefficient and its significance in wind turbine design, 3D aerodynamic effects and tip loss corrections, Dynamic stall and its impact on turbine blade performance. Aerodynamic optimization of wind turbine blades, Standards and processes for turbine performance testing, Power curve measurement and interpretation, Certification procedures and compliance requirements.	
UNIT – III: STRUCTURAL DYNAMICS AND DESIGN OF WIND TURBINES	**08 Hours**
Load analysis: aerodynamic, gravitational, and inertial forces, Natural frequencies, mode shapes, and resonance in turbine structures, Dynamic response and vibration analysis of turbine components, Fatigue life prediction and load spectrum analysis, Structural health monitoring systems and strategies, Design for reliability and mitigation of fatigue-induced failures, Material properties and selection criteria for wind turbine components.	
UNIT – IV: ELECTRICAL POWER CONVERSION AND GRID INTEGRATION	**09 Hours**
Types of wind turbine generators and power electronics, Power conversion and transmission systems in wind turbines, Challenges and strategies for integrating wind power into electrical grids, Role of energy storage in wind energy systems, Types of energy storage technologies: batteries, flywheels, pumped hydro,Hybrid systems combining wind power with other renewable sources.	
UNIT – V: OFFSHORE WIND ENERGY AND FUTURE TRENDS	**07 Hours**
Design and deployment challenges unique to offshore wind, Structural design of offshore wind turbines and floating platforms, Installation, operation, and maintenance of offshore wind farms, Recent advancements in wind turbine technology and materials. Emerging technologies: floating turbines, airborne wind energy, bladeless turbines, Future trends and potential developments in wind energy research and deployment.	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Assess and interpret wind resource data to determine optimal sites for wind farm development	L3
2	Analyze the aerodynamic forces acting on wind turbine blades using the Blade Element Momentum (BEM) theory. Optimize blade designs for enhanced efficiency through advanced aerodynamic principles.	L3
3	Design wind turbine components considering material properties, structural integrity, and fatigue life	L3
4	Develop and simulate control algorithms to optimize the performance and stability of wind turbines. Analyze the electrical power conversion processes and solve challenges related to grid integration of wind power.	L4
5	Evaluate the unique design, deployment, and maintenance challenges associated with offshore wind energy systems.	L4

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
COs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	1	2	1	-	-	-	-	-	-	-	-	-	1
CO2	2	2	3	-	-	-	-	-	-	-	-	-	1
CO3	2	2	3	-	-	-	-	-	-	-	-	-	1
CO4	1	1	3	-	-	-	-	-	-	-	-	-	1
CO5	2	2	3	-	-	-	-	-	-	-	-	-	1

Textbook:

1. Sørensen, J. D., & Sørensen, J. N. (2010). Wind Energy Systems. Woodhead Publishing.

Reference Books:

1. Centre for Wind Energy Technology (C-WET). Wind Energy Resources Survey in India. [No further details on publisher or publication year available for an accurate APA citation.]
2. Kaldellis, J. K. (2010). Stand-alone and Hybrid Wind Energy Systems. CRC Press.

E-Resources:

1. https://archive.nptel.ac.in/content/storage2/courses/108108078/pdf/chap6/teach_slides06.pdf
2. https://archive.nptel.ac.in/courses/103/103/103103206/

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MICRO ELECTRO MECHANICAL SYSTEMS (MEMS)

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23ME3610	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Introduce the fundamentals, design, and applications of MEMS technology.
2. Understand the properties and uses of various substrate materials and wafers in MEMS.
3. Learn the different fabrication processes used in MEMS manufacturing.
4. Explore the principles and applications of various types of micro sensors.
5. Study the design and functioning of microactuators and their systems.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : Introduction to MEMS	**07 Hours**
Definition – development- fundamentals of MEMS. Micro fluidics, microelectronics, micro systems- design and fabrication, working principles and applications. Integrated circuit processes, potential of MEMS in industry	

UNIT – II: Substrates and Wafers	**08 Hours**
Materials substrates and wafers, silicon substrate- properties of silicon, silicon compounds, silicon piezo resistors. Galium Arsenide, quartz, polymer for MEMS, conductive polymer. Shape memory alloys.	

UNIT – III: Fabrication Processes	**08 Hours**
Photolithography, photo resist applications, light sources, X-ray lithography, electron beam	

lithography, ion implantation, thin film deposition, diffusion process, Chemical and physical vapour deposition, bulk and surface machining, LIGA, laser ablation process. Micro stereolithography for 3D fabrication and nanolithography.	
UNIT – IV: Sensors	**07 Hours**
Sensor principles- Micro sensors, classification of physical sensors, integrated, intelligent or smart sensors, sensors principle, thermal sensors, electrical sensors, mechanical sensors, chemical and biosensors.	
UNIT – V: Microactuators	**09 Hours**
Electromagnetic and thermal microactuation, mechanical design of micro actuators, microactuator, micro valves, micro pumps, micro motors. Microactuator systems: Ink jet printers, micro-mirror TV projectors. Micro-opto- electromechanical systems, metal oxide semiconductor field effect transistor, multi-disciplinary applications.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Applying principles of microfluidics, microelectronics, and microsystems, understanding their working principles, and recognizing their potential applications in industry.
2	Evaluate and utilize the properties of silicon, silicon compounds, silicon piezo resistors, gallium arsenide, quartz, polymers, conductive polymers, and shape memory alloys in MEMS device innovation.
3	Implement advanced lithography and deposition techniques, including photolithography, X-ray lithography, electron beam lithography, laser ablation, micro stereolithography, and nanolithography, in MEMS fabrication.
4	Apply principles of various micro sensors, including thermal, electrical, mechanical, chemical, and biosensors, and to differentiate between physical, integrated, and intelligent sensors for advanced sensing applications.
5	Design and implement electromagnetic and thermal microactuation systems, including microactuators, microvalves, micropumps, and micromotors.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	1	2	1	-	-	-	-	-	-	-	-	-	1
CO2	2	2	3	-	-	-	-	-	-	-	-	-	1
CO3	2	2	3	-	-	-	-	-	-	-	-	-	1
CO4	1	1	3	-	-	-	-	-	-	-	-	-	1
CO5	2	2	3	-	-	-	-	-	-	-	-	-	1

Textbooks:

1. Senturia, S. D. (2000). Microsystem Design. Kluwer Academic Publishers.
2. Liu, C. (2011). Foundations of MEMS. Prentice Hall.

Reference Books:

1. Maluf, N., & Williams, K. (2004). Introduction to Microelectromechanical Systems Engineering (2nd ed.). Artech House.
2. Korvink, J. G., & Paul, O. (2005). MEMS: A Practical Guide of Design, Analysis, and Applications. Springer.

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Professional Elective-III

Robot Kinematics and Dynamics

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	: 23ME3612	**Credits**	: 03
Hours / Week	: 03 Hours	**Total Hours**	: 45 Hours
L–T–P–S	: 3–0–0–0		

Course Learning Objectives:

This Course will enable students to:

1. Deepen understanding of coordinate systems, transformations, and frame representations specifically applied to robotic systems.
2. Develop proficiency in analyzing and solving both forward and inverse kinematics problems for various types of robotic manipulators.
3. Enhance skills in calculating and interpreting differential motions and velocities in robotic systems to optimize operational efficiency.
4. Master dynamic modeling techniques, including Newton-Euler and Lagrangian methods, to accurately predict forces and motions in robotic mechanisms.
5. Explore advanced topics and current research trends in robot kinematics and dynamics to prepare for innovative problem-solving in robotics engineering.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : Introduction to Robotic Systems	**09 Hours**
Overview of Robotics: Types of robots and their applications. Coordinate Systems and Transformations: Frame representations, homogeneous coordinates, and transformation matrices specific to robotic applications. Review of Basic Kinematics and Dynamics: A brief recap emphasizing aspects uniquely applicable to robotic systems.	

UNIT – II: Forward and Inverse Kinematics of Robots	09 Hours
Forward Kinematics: Derivation of position and orientation for robotic manipulators. Inverse Kinematics: Solution techniques for position and orientation determination of the end-effector. Workspace Analysis: Determination of reachable spaces and dexterous workspaces in robotic systems. Jacobian and Singularities: Understanding the role of the Jacobian matrix in velocity and force analysis, and identifying singular configurations.	
UNIT – III: Differential Motions and Velocities	**06 Hours**
Differential Relationships: Mapping from joint velocities to end-effector velocities. Motion Trajectories: Planning and analysis of trajectories in joint space and Cartesian space for robots. Velocity Kinematics: Analysis of velocities within the context of robot manipulators and the implications of different configurations.	
UNIT – IV: Robot Dynamics	**07 Hours**
Dynamic Modeling and Equation Derivation: Application of Newton-Euler and Lagrangian methods to robotic systems. Forces and Torques: Computation for static and dynamic cases in robotic arms. Energy Methods in Robotics: Application of energy conservation principles to the analysis and simulation of robotic motion.	
UNIT – V: Advanced Topics in Robot Kinematics and Dynamics	**08 Hours**
Multi-body Dynamics: Analysis of complex robotic systems with multiple interconnected bodies. Nonlinear Dynamics of Robots: Study of behavior under non-linear conditions and impacts. Introduction to Computational Dynamics: Use of software tools for simulation and analysis of robotic kinematics and dynamics. Current Trends and Research in Robotic Kinematics and Dynamics: Discussion of recent advancements and future directions in the field.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply transformation matrices and coordinate system techniques to model complex robotic systems and solve spatial relationship problems.
2	Design and execute kinematic analyses to determine the position, orientation, and trajectory of robot manipulators in both forward and inverse configurations.
3	Apply differential kinematics and dynamics to analyze and optimize the velocity and acceleration profiles of robotic systems during operation.
4	Construct dynamic models of robots using advanced mathematical methods and validate these models through computational simulations to predict real-world behavior.
5	Apply and integrate current research and technological advances in robot kinematics and dynamics into practical applications and academic discussions, fostering innovation and scholarly discourse.

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
COs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	2	2	3	2	-	-	-	-	-	-	-	-	2
CO2	2	2	3	-	-	-	-	-	-	-	-	-	2
CO3	2	3	3	-	-	-	-	-	-	-	-	-	2
CO4	2	3	3	2	2	-	-	-	-	-	-	-	3
CO5	2	3	3	3	-	-	-	-	-	-	-	-	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. Siciliano, B., Sciavicco, L., Villani, L., & Oriolo, G. (2009). Robotics: Modelling, Planning and Control. Springer.
2. Craig, J. J. (2017). Introduction to Robotics: Mechanics and Control (4th ed.). Pearson.

Reference Books:

1. Spong, M. W., & Vidyasagar, M. (2008). Robot Dynamics and Control (2nd ed.). Wiley.
2. Angeles, J. (2014). Fundamentals of Robotic Mechanical Systems: Theory, Methods, and Algorithms (4th ed.). Springer.

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PROCESSING OF PLASTICS AND COMPOSITES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23ME3613	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the properties, classifications, and applications of various plastics and composite materials.
2. Learn and apply different processing techniques for manufacturing plastic products, focusing on process parameters and quality.
3. Explore and implement various composite processing techniques, ensuring process optimization and quality control.
4. Investigate advanced processing methods, including additive manufacturing and hybrid techniques, for plastics and composites.
5. Conduct mechanical and non-destructive testing, thermal analysis, and quality control procedures for plastics and composites, adhering to industry standards.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : Introduction to Plastics and Composites	**07 Hours**
Overview of plastics and composites, Classification and types of plastics, Types of composite materials, Basic properties and applications, Advantages and limitations	
UNIT – II: Processing Techniques for Plastics	**07 Hours**

Injection molding, Extrusion, Blow molding, Thermoforming, Rotational molding, Process parameters and their effects on product quality	
UNIT – III: Processing Techniques for Composites	**08 Hours**
Hand lay-up and spray-up, Filament winding, Pultrusion, Resin transfer molding (RTM), Compression molding, Autoclave and out-of-autoclave processing, Process parameters and quality control	
UNIT – IV: Advanced Processing Methods	**09 Hours**
Additive manufacturing for plastics and composites, Advanced injection molding techniques, Vacuum-assisted resin infusion, Automated fiber placement (AFP) and automated tape laying (ATL), Hybrid processing techniques, Nano-composites processing	
UNIT – V: Testing and Quality Control	**08 Hours**
Mechanical testing of plastics and composites, Non-destructive testing methods, Thermal analysis and characterization techniques, Quality control in manufacturing processes, Standards and specifications for plastics and composites, Case studies on quality control and failure analysis	

Course Outcome	Description
1	**Differentiate** between various types of plastics and composites based on their properties and applications.
2	**Analyze** the impact of process parameters on product quality in different plastics processing techniques.
3	**Evaluate** various processing techniques for composites, focusing on process parameters and quality control.
4	**Examine** advanced processing methods for plastics and composites, including additive manufacturing and hybrid techniques.
5	**Interpret** testing and quality control methods for plastics and composites, utilizing case studies for failure analysis.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	2	2	-	-	-	-	-	-	-	-	-	2
CO2	2	3	3	3	-	-	-	-	-	-	-	-	1
CO3	2	3	3	3	-	-	-	-	-	-	-	-	1
CO4	2	3	3	2	-	-	-	-	-	-	-	-	1
CO5	2	3	3	2	-	-	-	-	-	-	-	-	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Textbooks:

1. Crawford, R. J., & Throne, J. L. (2012). Plastics Engineering (3rd ed.). Butterworth-Heinemann.
2. Chawla, K. K. (2012). Composite Materials: Science and Engineering (3rd ed.). Springer.

Reference Books:

1. Muccio, E. A. (1994). Understanding Plastics Engineering and Manufacturing: A Practical Guide. Hanser Gardner Publications.
2. Gibson, R. F. (2016). Principles of Composite Material Mechanics (4th ed.). CRC Press.

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SOFTWARE DEFINED VEHICLES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23ME3614	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This course will enable students to:

1. Understand the architecture, components, and design principles of Software Defined Vehicles.
2. Apply embedded systems, real-time operating systems, and control algorithms to SDV development.
3. Analyze communication protocols and data exchange in SDV environments.
4. Learn safety, cybersecurity, and regulatory aspects associated with software-driven vehicles.
5. Develop design skills for software integration, testing, and over-the-air updates in modern vehicles.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** **-** and when that's possible, it helps improve the student's understanding.

UNIT – I	**08 Hours**

INTRODUCTION TO SOFTWARE DEFINED VEHICLES

Evolution of SDV: Traditional vs Software Defined Architecture, Key Enablers: ECU consolidation, domain controllers, zonal architecture, Functional Domains: ADAS, infotainment, powertrain, body control, autonomous systems, SDV Stack: Hardware layer, middleware, application layer, Real-time Operating Systems (RTOS) in SDVs.

UNIT – II	**8 Hours**

EMBEDDED SYSTEMS FOR SDV

Embedded controllers, SoCs, microcontrollers used in automotive domain, Sensor integration: LiDAR, RADAR, cameras, IMU, ultrasonic sensors , Control algorithms for perception, localization, decision making, Middleware platforms: AUTOSAR Classic & Adaptive Platforms, Time synchronization & sensor fusion.	
UNIT – III	**08 Hours**
COMMUNICATION NETWORKS & PROTOCOLS In-vehicle communication protocols: CAN, LIN, FlexRay, MOST, Automotive Ethernet , Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) communication , Diagnostics over IP (DoIP) , Functional safety communication standards: ISO 26262, Controller Area Network with Flexible Data-Rate (CAN-FD)	
UNIT – IV	**08 Hours**
SDV SOFTWARE INTEGRATION, TESTING & UPDATES Software architecture design: model-based design, code generation, Software verification and validation: SIL, HIL, MIL testing, Over-the-Air (OTA) software updates: architecture, challenges, and strategies, AI/ML applications in predictive maintenance & performance optimisation, Software version control & deployment strategies.	
UNIT – V	**07 Hours**
SAFETY, SECURITY & REGULATORY FRAMEWORKS Functional Safety: ISO 26262 , Automotive Cybersecurity: ISO/SAE 21434, Risk assessment, encryption & secure bootloader , Legal, ethical, and regulatory challenges in autonomous & software-driven vehicles, Case studies: Tesla, Google Waymo, NIO, ZF, Bosch	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Apply the principles of embedded systems, sensors, and control algorithms in vehicle software architecture.	L3
2	Analyze data communication protocols like CAN, LIN, and Ethernet used in SDV platforms.	L4
3	Apply software integration and validation methods for autonomous and connected vehicle features.	L3
4	Evaluate safety, cybersecurity, and over-the-air update mechanisms for software-driven vehicle systems.	L3
5	Design and develop system-level solutions for SDV functionality using model-based development tools.	L3

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)										PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	2	2	-	-	-	-	-	-	-	-	-	2
CO2	2	3	3	3	-	-	-	-	-	-	-	-	1
CO3	2	3	3	3	-	-	-	-	-	-	-	-	1
CO4	2	3	3	2	-	-	-	-	-	-	-	-	1
CO5	2	3	3	2	-	-	-	-	-	-	-	-	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

Text Books

1. Hans-Werner Wuerz, Software-Defined Vehicles: Automotive Architecture Transformation, Springer, 2022.

2. Nicolas Navet & Francoise Simonot-Lion, Automotive Embedded Systems Handbook, CRC Press.

Reference Books

1. Roger C. Lanctot, The Software-Defined Car: Automotive Innovation Reimagined, SAE International.

2. MathWorks Documentation — Model-Based Design for Automotive.

3. ISO 26262 & ISO/SAE 21434 Standards (latest versions).

4. SAE Technical Papers on Connected & Autonomous Vehicles.

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HYDROGEN ENERGY AND STORAGE
[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23ME3615	**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Describe historical developments and current advancements in hydrogen technologies. Identify the unique properties of hydrogen relevant to its use as a fuel.
2. Analyse various production methods such as steam methane reforming, electrolysis, and biomass conversion
3. Identify key components of hydrogen distribution systems, including pipelines and refuelling stations.
4. Describe the working principles and components of various types of fuel cells
5. Conduct life cycle assessments to evaluate the environmental footprint of hydrogen production, storage, and utilization.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : OVERVIEW OF HYDROGEN ENERGY:	**06 Hours**
History and development of hydrogen technologies, Hydrogen as an energy carrier in modern energy systems, Global energy challenges and the role of hydrogen, Physical and chemical properties of hydrogen, Hydrogen's advantages and challenges as a fuel, Safety considerations in handling hydrogen,	
UNIT – II: HYDROGEN PRODUCTION TECHNOLOGIES:	**08 Hours**
Conventional Hydrogen Production, Steam Methane Reforming (SMR) and Partial Oxidation.	

Coal Gasification and other fossil fuel-based methods, Water Electrolysis (Alkaline, PEM, SOEC). Biological and Photolytic production processes, Thermochemical cycles, Novel methods and future trends in hydrogen production, Hydrogen production from biomass and waste materials.	
UNIT – III: HYDROGEN STORAGE AND DISTRIBUTION	**09 Hours**
Compressed Gas and Liquid Hydrogen Storage, Cryo-compressed hydrogen storage, Solid-state storage (Metal Hydrides, Chemical Hydrides), Carbon-based storage materials and other novel methods, Material considerations and safety in hydrogen storage. Hydrogen distribution systems: Pipelines, trucking, and shipping, Infrastructure requirements for hydrogen refueling stations, Technological challenges and solutions in hydrogen logistics, Economic feasibility and scalability of hydrogen distribution networks	
UNIT – IV : FUEL CELL TECHNOLOGIES AND APPLICATIONS	**08 Hours**
Fundamentals of fuel cells: PEMFC, SOFC, MCFC, etc, Components and operation of fuel cells. Applications of fuel cells in transport, stationary power, and portable devices, Efficiency analysis and comparison with conventional energy systems.	
UNIT – V	**08 Hours**
Evaluate the financial viability and market potential of hydrogen technologies, including production, storage, and distribution, using economic modeling and cost-benefit analysis frameworks	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Analyze the significance of hydrogen as an energy carrier in the context of global energy demands. Formulate safety protocols and strategies for handling hydrogen based on its properties.
2	Evaluate and justify the selection of hydrogen production methods based on efficiency, environmental impact, and scalability
3	Analyze and compare the various hydrogen storage technologies, including compressed gas, liquid hydrogen, cryo-compressed hydrogen, solid-state storage (metal hydrides and chemical hydrides), and carbon-based storage materials.
4	Evaluate and differentiate the operational principles and characteristics of different types of fuel cells, including Proton Exchange Membrane Fuel Cells (PEMFC), Solid Oxide Fuel Cells (SOFC), and Molten Carbonate Fuel Cells (MCFC).
5	Evaluate the financial viability and market potential of hydrogen technologies, and also Assess the environmental impacts of hydrogen energy systems

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	2	1	-	-	1	-	-	-	-	-	-	-
CO2	1	2	1	-	-	1	-	-	-	-	-	-	1
CO3	1	2	1	1	-	-	-	-	-	-	-	-	1
CO4	1	2	1	-	-	1	-	-	-	-	-	-	1
CO5	1	2	1	-	-	2	-	-	-	1	-	-	-

TEXT BOOKS:

1. Bent Sørensen and Giuseppe Spazzafumo (2018), Hydrogen and Fuel Cells, Woodhead Publishing, Elsevier Science
2. Paul Ekins(2010), Hydrogen Energy, Earthscan

REFERENCE BOOKS:

1. Detlev Stolten (2011), Hydrogen and Fuel Cells. Fundamentals, Technologies and Applications, Wiley, John & Sons

E-Resources:

1. https://onlinecourses.nptel.ac.in/noc22_ch66/preview
2. https://nptel.ac.in/courses/103101215

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SUPPLY CHAIN MANAGEMENT
[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

Course Code	:	23ME3616	**Credits**	:	03
Hours / Week	:	04 Hours	**Total Hours**	:	45
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:
This course will enable students to:

1. Provide foundational knowledge of supply chain management principles, its evolution, and its role in business and the economy.
2. Introduce strategic sourcing, outsourcing decisions, supplier development, and world-class sourcing practices.
3. Familiarize students with warehouse management, materials handling, distribution network design, and facility location models.
4. Develop the ability to apply optimization models, demand planning, inventory management, and pricing strategies in uncertain environments.
5. Expose students to contemporary trends such as supply chain integration, IT applications, agile and reverse logistics, and future developments in supply chain management.

Teaching-Learning Process (General Instructions)
These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of different additive manufacturing methods

UNIT – I	**08 Hours**

Introduction:
Supply Chain – Fundamentals –Evolution- Role in Economy - Importance - Decision Phases – Supplier Manufacturer-Customer chain. - Enablers/ Drivers of Supply Chain Performance.

Supply chain strategy - Supply Chain Performance Measures.	
UNIT – II	**08Hours**
Strategic Sourcing Outsourcing Make Vs Buy - Identifying core processes - Market Vs Hierarchy - Make Vs buy continuum -Sourcing strategy - Supplier Selection and Contract Negotiation. Creating a world class supply base- Supplier Development - World Wide Sourcing. .	
UNIT – III	**06 Hours**
Warehouse Management Stores management- stores systems and procedures-incoming materials controlstores accounting and stock verification Obsolete, surplus and scrap-value analysis-material handlin g transportation and traffic management -operational efficiency-productivity-cost effectiveness-performance measurement. Supply Chain Network Distribution Network Design – Role - Factors Influencing Options, Value Addition – Distribution Strategies - Models for Facility Location and Capacity allocation. Distribution Center Location Models.	
UNIT – IV	**08 Hours**
Supply Chain Network optimization models. Impact of uncertainty on Network Design - Network Design decisions using Decision trees. Planning Demand, -multiple item -multiple location inventory management. Pricing and Revenue Management.	
UNIT – V	**09 Hours**
Current Trends: Supply Chain Integration - Building partnership and trust in Supply chain Value of Information: Bullwhip Effect - Effective forecasting - Coordinating the supply chain. Supply Chain restructuring, Supply Chain Mapping - Supply Chain process restructuring, Postpone the point of differentiation – IT in Supply Chain - Agile Supply Chains -Reverse Supply chain. Future of IT in supply chain- EBusiness in supply chain.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	**Analyze** the evolution, key drivers, and performance measures of supply chain management to optimize decision-making across supplier-manufacturer-customer chains.
2	Evaluate various sourcing strategies, supplier selection processes, and global sourcing models to develop world-class supplier networks.
3	Design warehouse management systems, stores procedures, and distribution networks considering operational efficiency, cost-effectiveness, and facility location models.
4	Develop network optimization models and decision trees for demand planning, multi-location inventory management, and pricing strategies under uncertainty.
5	Critically assess emerging trends such as supply chain integration, bullwhip

effect mitigation, IT enablement, and agile/reverse supply chains for future-ready supply chain structures.

Table: Mapping Levels of COs to POs / PSOs

COs	Program											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	1	1	2	1	1	1	1	-	-	-	2	2
CO2	1	1	1	2	2	1	-	-	-	-	-	2	2
CO3	1	1	2	1	2	2	-	1	-	-	-	2	3
CO4	1	1	1	1	2	1	-	1	-	-	-	2	2
CO5	2	2	1	2	-	-	1	1	-	-	-	3	2

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS :

1. Supply Chain Management– Text and Cases Janat Shah Pearson Education 2009.
2. Supply Chain ManagementStrategy Planning and Operation Sunil Chopra and Peter Meindl PHI Learning / Pearson Education 2007

REFERENCES :

1. Business Logistics and Supply Chain Management Ballou Ronald H Pearson Education 5th Edition, 2007
2. Designing and Managing the Supply Chain: Concepts, Strategies, and Cases David Simchi-Levi, Philip Kaminsky, Edith Simchi-Levi Tata McGraw-Hill 2005

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FUNDAMENTALS OF ECONOMICS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. **Realize** importance of Fundamentals of economics in Engineering.
2. **Comprehend** the ideas of Time value of money and Inflation.
3. **Explain** Present worth and equivalent annual worth calculations
4. **Demonstrate** Economic planning and finance commission and its importance
5. **Recognize** the importance of taxation, RBI and its monetary operations and public finance

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** **-** and when that's possible, it helps improve the students' understanding.

UNIT – I	**08 Hours**
Introduction to Engineering economics, Engineering decision makers, engineering and economics, problem solving and decision making, strategy and tactics, factors of production, Production possibility schedule and curve, marginal rate of transformation, Concept of economic growth. ***(Text Book-1: Chapter 1: 1.1 to 1.4, Chapter 2: 2.1 to 2.4)***	

UNIT – II	**08 Hours**
Time value of money - Simple interest, compound interest – nominal interest rate, effective interest rate, and inflation. ***(Text Book-1: Chapter 2: 2.1-2.7).***	

UNIT – III	07 Hours
Present worth calculations, Equivalent Annual worth Comparison methods, Situations for Equivalent Annual worth Comparison, Consideration of asset life, comparison of assets with equal and unequal lives. ***(Text Book-1: Chapter 3: 3.1 to 3.5)***	
UNIT – IV	**08 Hours**
Economic Planning- Regional planning, National planning and Inclusive development. Planning in India- Vishveshwaraiah Plan, Bombay Plan, Gandhian Plan, Harrod Domar plan, Main objectives of Planning, Relevance of Planning in Economic reforms of the Nation, Five year plans, Finance commission and its functions ***(Text Book-2: Chapter 4: 4.4 to 4.6, Chapter- 5: 5.2,5.5, to 5.7, 5.19- 5.27, 5.33, 5.38,)***	
UNIT – V	**08 Hours**
The idea of National income- GDP, GNP, NDP and NNP, Types of economic sectors- primary, secondary and tertiary, Reserve Bank of India and its Monetary operations, Tax structure in India and GST, Public Finance in India- Budgetary terms ***(Text Book-2: Chapter 1: 1.13, 1.14-1.17, Chapter 12: 12.4- 12.8, Chapter 17: 17.3-17.4, 17.7***)	

Course Outcome	Description
At the end of the course the student will be able to:	
1	**Apply** the principles of engineering economics to make informed engineering decisions, considering both economic and technical factors.
2	**Analyze** the impact of time value of money on engineering projects, calculating present and future values using simple and compound interest, nominal and effective interest rates, and accounting for inflation.
3	Evaluate various economic alternatives using present worth and equivalent annual worth comparison methods, considering asset life and the comparison of assets with equal and unequal lives.
4	**Design** economic plans at regional and national levels by understanding and applying different planning strategies, such as the Vishveshwaraiah Plan, Bombay Plan, Gandhian Plan, and Harrod Domar plan, and by evaluating the relevance of these plans in the context of economic reforms.
5	**Implement** knowledge of national income concepts (GDP, GNP, NDP, and NNP) and the structure of economic sectors to assess the economic environment, understand the role of the Reserve Bank of India, analyze the tax structure and GST, and interpret budgetary terms in the context of public finance in India.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	1	1	-	-	1	1	-	2	1	1	1	1
CO2	1	1	1	-	-	1	1	-	2	1	1	1	1
CO3	1	1	1	-	-	1	1	-	2	1	1	1	1

CO4	1	1	1	-	-	1	1	-	2	1	1	1	1
CO5	1	1	1	-	-	1	1	-	2	1	1	1	1

3: Substantial (High) **2: Moderate (Medium)** **1: Poor (Low)**

TEXT BOOKS:

1. Riggs, J., Bedworth D., & Randhawa S., (2011), **Engineering Economics,** 4th Edition, McGraw-Hill Education.
2. Ramesh Singh., (2023-24), Indian Economy, 15th Edition, McGraw- Hill Publications

REFERENCE BOOKS:

1. Panneerselvam R, (2013), **Engineering Economics,** 2nd edition, Prentice Hall India Learning Private Limited

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INSTRUMENTATION AND CONTROL

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	:	03
Hours / Week	:	04 Hours	**Total Hours**	:	30+30Hours
L–T–P–S	:	2–0–2–0			

Course Learning Objectives:

This course provides an introduction to the fundamental concepts of instrumentation and control engineering. It is designed for undergraduate students and covers essential topics in instrumentation and basic control systems, ensuring students gain foundational knowledge.

1. Explain the operating principles of various measurement systems and how they apply to engineering problems.
2. Describe the fundamental roles of sensors, transducers, and signal conditioning in instrumentation systems
3. Illustrate the basic structure and function of control systems through examples and mathematical models.
4. Evaluate control system performance using time-domain and frequency-domain analysis techniques.
5. Apply control theories and methods to design simple control systems for practical engineering applications.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improv the students' understanding.

UNIT – I Introduction to Instrumentation	**05 Hours**
Introduction to Instrumentation, Overview of instrumentation in engineering. Importance and applications in various systems. SI units and standards in measurement. Importance of accuracy and calibration	
UNIT – II: Basic Components of Instrumentation	**05 Hours**

Sensors and Transducers Types and working principles of sensors (e.g., temperature, pressure, force. Applications in different engineering fields. Signal processing: filters, amplifiers, and converters. Importance of noise reduction and data accuracy.	
UNIT – III: Introduction to Control Systems	**05 Hours**
Basics of Control Systems, Introduction to open-loop and closed-loop control systems. Examples in engineering (e.g., temperature, speed control). Mathematical Modelling of Control Systems Transfer functions and block diagrams. Modelling of engineering systems (e.g., mass-spring-damper, fluid systems).	
UNIT – IV: Analysis of Control Systems	**05 Hours**
Frequency-Domain Analysis Frequency response analysis using Bode plots. Interpretation of frequency response characteristics. Time-Domain Analysis of transient and steady-state responses. Time-domain specifications (rise time, settling time, overshoot).	
UNIT – V: Basic Design of Control Systems	**06 Hours**
PID Controllers Application of Proportional, Integral, and Derivative controllers. Tuning methods and practical considerations. Stability and Performance Stability analysis using root locus and other techniques. Design for stability and performance in control applications **Case studies** in various engineering systems (e.g., vibration control, thermal systems).	

LIST OF LABORATORY/PRACTICAL EXPERIMENTS ACTIVITIES TO BE CONDUCTED (IF ANY) **TOTAL 30 HRS**

1. **To determine the characteristics of different sensors and transducers**: Students will use various sensors (temperature, pressure, force) to collect data, focusing on understanding their operating principles and response behaviors.
2. **To calibrate and test signal processing equipment**: This experiment will involve calibrating filters, amplifiers, and converters to understand the importance of accuracy and noise reduction in data recording.
3. **To model and analyze a basic control system using transfer functions and block diagrams**: Students will construct a mathematical model of a simple engineering system (like a mass-spring-damper system), and simulate its behavior to understand the fundamentals of control systems.
4. **To analyze the frequency and time-domain responses of a control system**: Students will perform frequency response analysis using Bode plots and time-domain analysis to observe transient and steady-state responses, measuring parameters such as rise time, settling time, and overshoot.
5. **To design and tune a PID controller for a specific control application**: In this experiment, students will apply a PID controller to a control system, such as a temperature or speed control system, and tune it to optimize stability and performance using methods like root locus.

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply the principles of instrumentation to select and utilize appropriate sensors and transducers for measuring physical quantities (e.g., temperature, pressure, force) in diverse engineering applications.
2	Analyze signal processing components, such as filters, amplifiers, and converters, to enhance noise reduction and data accuracy in measurement systems.
3	Evaluate the performance of control systems by constructing and interpreting mathematical models using transfer functions and block diagrams, and differentiating between open-loop and closed-loop systems.
4	Design control systems by conducting frequency-domain and time-domain analysis, utilizing techniques like Bode plots and transient response analysis to meet specific performance criteria (e.g., rise time, settling time, overshoot).
5	Apply and tune PID controllers in practical engineering scenarios, employing stability analysis methods such as root locus to ensure optimal control system performance and stability in applications like vibration control and thermal systems.

Table: Mapping Levels of COs to POs / PSOs													
COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	1	1	1	2	-	-	-	-	-	-	1	1
CO2	1	1	1	1	2	-	-	-	-	-	-	1	1
CO3	1	1	1	1	2	-	-	-	-	-	-	1	1
CO4	1	1	1	1	2	-	-	-	-	-	-	1	1
CO5	1	1	1	1	2	-	-	-	-	-	-	1	1

Textbooks:

1. Nakra, B. C., & Chaudhary, K. K. (2003). Instrumentation, Measurement and Analysis (3rd ed.). McGraw-Hill Education.
2. Nagrath, I. J., & Gopal, M. (2009). Control Systems Engineering (5th ed.). New Age International Publishers. ISBN: 9788122420080.

Reference Books:

1. Ogata, K. (2009). Modern Control Engineering (5th ed.). Prentice Hall.
2. Doebelin, E. O. (2004). Measurement Systems: Application and Design (5th ed.). McGraw-Hill Education.

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OPEN ELECTIVE-2

AUTOMOBILE ENGINEERING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the basic principles of automobile engineering, including vehicle dynamics, propulsion systems, and the integration of mechanical components.
2. Develop a comprehensive understanding of electric vehicles, including their architecture, key components, and the underlying electrical systems.
3. Acquire knowledge of hybrid technologies and advanced propulsion systems, focusing on their design, functionality, and environmental impact.
4. Gain insights into advanced driver-assistance systems (ADAS), exploring their technological foundations, operational mechanisms, and benefits.
5. Explore the design considerations, safety standards, and regulatory requirements applicable to modern automobiles, particularly electric and hybrid vehicles.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** **-** and when that's possible, it helps improve the students' understanding.

UNIT – I : Fundamentals of Automobile Engineering	**06 Hours**
Overview of Automobile Systems: Introduction to the various systems in automobiles such as chassis, transmission, engine, braking, and steering systems.Automotive Materials and Manufacturing Processes: Study of materials used in automotive manufacturing, including emerging materials for lightweight construction.	
UNIT – II: Electric Vehicles (EVs)	**09 Hours**
Introduction to Electric Vehicles: History and evolution of EVs, comparison with internal	

combustion engine vehicles. EV Architecture and Systems: Detailed study of electric vehicle components including batteries, electric motors, controllers, and regenerative braking systems. Battery Technology and Management Systems: Types of batteries used in EVs, battery management systems, charging technologies, and strategies for enhancing battery life.	
UNIT – III: Hybrid and Advanced Propulsion Systems	**09 Hours**
Hybrid Vehicle Technologies: Overview of hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and their drivetrain configurations. Advanced Propulsion Technologies: Fuel cell vehicles (FCVs), solar-powered vehicles, and alternative fuels. Thermal Management in EVs and HEVs: Heat generation and cooling requirements, strategies for managing thermal loads in electric and hybrid vehicles.	
UNIT – IV: Advanced Driver-Assistance Systems (ADAS)	**07 Hours**
Fundamentals of ADAS: Introduction to ADAS and its role in improving safety and driving comfort. Key ADAS Technologies: Sensors and actuators used in ADAS such as cameras, radar, LIDAR, ultrasonic sensors, and their integration into vehicle systems. ADAS Features: Detailed study of features such as adaptive cruise control, lane keeping assist, automatic parking, and collision avoidance systems.	
UNIT – V: Design and Safety Considerations	**08 Hours**
Vehicle Design for Safety: Design principles for occupant safety, pedestrian safety, and crashworthiness. Regulatory and Testing Standards: Overview of global safety standards, emissions regulations for EVs and HEVs, and testing protocols. Future Trends and Innovations: Autonomous vehicles, vehicle connectivity (V2X), and emerging trends in vehicle design and safety.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Analyse the historical evolution of electric vehicles (EVs) and hybrid electric vehicles (HEVs) and compare them with internal combustion engine vehicles in terms of efficiency and environmental impact.
2	Design an electric vehicle architecture by integrating key components such as batteries, electric motors, controllers, and regenerative braking systems, ensuring optimal performance and safety.
3	Evaluate advanced propulsion technologies, including fuel cell vehicles and solar-powered vehicles, to determine their feasibility and potential advantages in modern transportation systems.
4	Apply advanced driver-assistance systems (ADAS) technologies to enhance vehicle safety and driving comfort, including the implementation of sensors and actuators such as cameras, radar, and LIDAR
5	Develop comprehensive vehicle design strategies that prioritize occupant safety, pedestrian safety, and compliance with global regulatory and testing standards, while incorporating future trends such as autonomous driving and vehicle connectivity

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	1	2	1	1	-	-	-	-	-	-	-	-	-
CO2	1	2	1	1	-	-	-	-	-	-	-	-	-
CO3	1	2	1	1	-	-	-	-	-	-	-	-	-
CO4	1	2	1	1	-	-	-	-	-	-	-	-	-
CO5	1	1	1	1	-	-	-	-	-	-	-	-	-

Textbooks:

1. Ehsani, M., Gao, Y., Longo, S., & Ebrahimi, K. (2018). Modern Electric, Hybrid Electric, and Fuel Cell Vehicles (3rd ed.). CRC Press.
2. Erjavec, J., & Thompson, R. (2014). Automotive Technology: A Systems Approach (6th ed.). Cengage Learning.

Reference Books:

1. Denton, T. (2016). Advanced Automotive Fault Diagnosis: Automotive Technology: Vehicle Maintenance and Repair (4th ed.). Routledge.
2. Husain, I. (2011). Electric and Hybrid Vehicles: Design Fundamentals (2nd ed.). CRC Press.

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TOTAL QUALITY MANAGEMENT AND RELIABILITY

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the evolution and importance of quality control and learn the fundamental principles of Total Quality Management (TQM).
2. Master the application of quality improvement tools such as Kaizen, Six Sigma, and quality circles to enhance organizational processes.
3. Gain proficiency in establishing and maintaining Quality Management Systems, including familiarity with ISO 9000 and ISO 14000 standards.
4. Develop skills in assessing and improving product reliability through quantitative measures and reliability engineering techniques.
5. Learn to perform risk assessments and design for reliability, incorporating redundancy and robustness into product designs.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyze information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improv the students' understanding.

UNIT – I Quality Control	**09 Hours**

Quality Control

Management of product quality, evolution of quality control, changing quality concepts, modern concept of total quality management, contribution of quality masters (Deming, Juran, Crosby, Ishikawa, Taguchi), process control charts; statistical quality control tools; statistical process control and process capability.

(***CHAPTER -1)***

UNIT – II: Total Quality Management	**09 Hours**

Total quality management, concept of total quality, total quality maintenance, total quality in service sector; role of customer and people in total quality management; steps for quality improvement, Kaizen; organizing for effective quality management; creating quality by design assessment of customer's needs; formulation of design specifications; standardization; costs of quality; quality circles; 5-S concept; zero defect program; Six– Sigma approach.(***CHAPTER-2,3)***	
UNIT – III: Quality Management Systems	**08 Hours**
Quality Management Systems: ISO 9000 series of standard; ISO 14000 series of standards, Strategic tools and techniques for TQM, need for tools and techniques in TQM; commonly used tools for TQM; approaches and deployment of tools for quality planning – quality function deployment (QFD), concurrent engineering; tools for continuous improvement -Deming's Plan – Do – Check – Act (PDCA) cycle, Poka – Yoke (Mistake – Proofing), Taguchi's quality loss function.***(CHAPTER 4)***	
UNIT – IV: Reliability	**06 Hours**
Reliability, concept and definition, reliability parameters: Reliability as a function of time, failure rate as a function of time, constant failure rate, mean time to failure (MTTF), MTTF as a function of failure rate, mean time between failure (MTBF), mean down time (MDT), maintainability & availability, increasing failure rate, bath-tub curve; Weilbull distribution, System reliability models: series system, parallel system, series-parallel system, six sigma approach in reliability.(**CHAPTER 1)**	
UNIT – V: Risk Assessment & Reliability in Design	**07 Hours**
Risk assessment & reliability design, causes of failures, failure modes & effects analysis (FMEA), faulty tree analysis (FTA); Tribological failure and monitoring techniques; Design based on reliability, redundancy in design**.(CHAPTER 2,3)**	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Analyze quality management principles, including TQM, quality masters' contributions, and statistical quality control tools, to enhance process capability.
2	Implement the principles and steps involved in Total Quality Management (TQM) and Kaizen, and explain how these methods improve organizational performance.
3	Apply ISO 9000 and ISO 14000 standards in developing quality management systems. Students will practice using these standards to ensure compliance and improve quality.
4	Analyze reliability concepts such as MTTF, MTBF, and the bath-tub curve, and assess how these parameters impact system performance and maintenance.
5	Apply Failure Modes and Effects Analysis (FMEA) and Fault Tree Analysis (FTA) to conduct risk assessments, identify potential failures, and develop effective mitigation strategies.

Table: Mapping Levels of COs to POs / PSOs

COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	3	2	2	2	-	-	-	-	-	-	1	2

CO2	3	3	2	2	2	1	-	-	-	-	-	-	2
CO3	3	3	3	2	2	2	2	-	-	-	-	1	2
CO4	3	3	3	2	1	1	-	-	-	-	-	-	2
CO5	3	3	2	2	2	1	-	-	-	-	-	1	2

Textbook:

1. Lal, H. (2015). Total Quality Management – A Practical Approach. New Age International (P) Ltd. Publishers.
2. Mondal, S. K. (2009). Total Quality Management Principles and Practice. Vikas Publishing House Pvt. Ltd.

Reference Books:

1. Feigenbaum, A. V. (1991). Total Quality Control. McGraw-Hill Book Company.
2. Juran. (1988). Quality Control Handbook. McGraw-Hill Book Company.

E-Resources:

https://kanchiuniv.ac.in/coursematerials/ECE_COURSE_MATERIAL_ODD%20SEMESTER/ECE_COURSE%20MATERIAL_ODD%20SEMESTER/Mrs.V.UMA_TOTAL%20QUALITY%20MANAGEMENT.pdf

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RENEWABLE ENERGY SOURCES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the fundamental principles and social implications of renewable energy, and analyze its availability and applications worldwide and specifically in India.
2. Acquire knowledge of solar energy technologies, including the mechanics of solar radiation, thermal collectors, and photovoltaic systems.
3. Explore wind energy fundamentals, including wind characteristics, energy capture, and efficiency calculations for wind turbine installations.
4. Learn the processes involved in biomass energy production, including different biomass fuels, conversion techniques, and biogas generation.
5. Study the principles and applications of tidal and ocean thermal energy, and investigate new energy sources like hydrogen for sustainable development.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : Introduction	06 Hours
Principles of renewable energy; energy and sustainable development, fundamentals and social implications. worldwide renewable energy availability, renewable energy availability in India, brief descriptions on solar energy, wind energy, tidal energy, wave energy, ocean thermal energy, biomass energy, geothermal energy, oil shale. Introduction to Internet of energy (IOE).***(Text Book-1: Chapter 1: 1.1 to 1.2)***	

UNIT – II: Solar Energy	**10 Hours**
Solar Energy- Solar radiation its measurements and prediction - solar thermal collectors - flat plate collectors, concentrating collectors – applications - heating, cooling, desalination, drying, cooking, etc. Principle of photovoltaic conversion of solar energy - types of solar cells and fabrication -photovoltaic applications - battery charging, domestic lighting, street lighting. ***(Text Book-1: Chapter 2.1: 2.12).***	
UNIT – III:Wind Energy	**08 Hours**
Wind Energy- Wind energy - energy chains - application - historical background, merits and limitations - nature of wind - planetary and local day / night winds - wind energy quantum - power in wind- turbine efficiency - torque thrust calculations - velocity at different heights - site selection - components of wind energy conversion system (WECS). ***(Text Book-1: Chapter 6: 6.1 to 6.16)***	
UNIT – IV: Energy from Biomass	**06 Hours**
Energy from biomass - biomass as renewable energy source - types of bio mass fuels - solid, liquid and gas - biomass conversion techniques- wet process, dry process photosynthesis-biogas generation - factors affecting bio- digestion - classification of bio gas plant - continuous, batch and fixed dome types - advantages and disadvantages . ***(Text Book-1: (Chapter 07: 7.1 to 7.13)***	
UNIT – V: Tidal, Ocean Thermal Energy and New Energy Sources	**09 Hours**
Tidal Energy: tide – spring tide, neap tide – tidal range – tidal power – types of tidal power plant – single and dual basin schemes – requirements in tidal power plant - ocean thermal energy conversion (OTEC): principle - open and closed OTEC cycles. Hydrogen as a renewable energy source - sources of hydrogen - fuel for vehicles - hydrogen production.fuel cell – principle of working, construction and applications ***(Text Book-1: Chapter 8,9 &11): 8.1 to 8.06,9. to 9.10 & 11.1 to 11.8)***	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Evaluate the global and local implications of renewable energy sources and apply sustainable practices and technologies in energy projects.
2	Design and optimize solar energy systems for a variety of applications, including heating, cooling, and power generation, using knowledge of solar radiation and photovoltaic technologies.
3	Analyze and implement wind energy solutions by understanding wind dynamics, assessing site potential, and calculating energy yields and system efficiencies.
4	Develop and manage biomass energy projects by applying various conversion techniques and understanding the operational parameters of different types of biogas plants.
5	Design and assess tidal and ocean thermal energy systems, and integrate emerging technologies such as hydrogen fuel cells into renewable energy solutions.

Table: Mapping Levels of COs to POs / PSOs

COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	3	2	-	-	2	-	-	-	-	1	-	2

CO2	3	3	3	-	-	1	-	-	-	-	1	-	3
CO3	3	3	3	-	-	1	-	-	-	-	1	-	2
CO4	3	3	3	-	-	1	-	-	-	-	1	-	-
CO5	3	2	3	-	-	1	-	-	-	-	1	3	3

Textbooks:

1. Rai, G. D. (2010). Non-conventional Resources of Energy (4th ed.). Khanna Publishers.
2. Khan, B. H. (2009). Non-Conventional Energy Resources (2nd ed.). McGraw Hill.

Reference Books:

3. Rao, S., & Parulekar, B. B. (2005). Energy Technology (4th ed.). Khanna Publishers.
4. Mackay, D. J. C. (2009). Sustainable Energy – Without the Hot Air. UIT Cambridge. (Note: Corrected publisher information for accuracy)

E-Resources:

1. https://www.renewableenergyworld.com/
2. https://www.renewableenergyhub.co.uk/
3. https://www.edfenergy.com/energywise/renewable-energy-sources
4. https://www.energy.gov/eere/renewable-energy

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RAPID MANUFACTURING TECHNOLOGIES

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the historical development and fundamental principles of rapid prototyping technologies and their impact on modern manufacturing and design.
2. Gain proficiency in operating and applying various liquid-based, solid-based, and powder-based rapid prototyping systems.
3. Learn the technical aspects and applications of advanced rapid prototyping processes such as Stereolithography, Fused Deposition Modeling, and Selective Laser Sintering.
4. Explore the range of materials available for rapid prototyping, including polymers, metals, ceramics, and composites, and their specific applications in prototyping and manufacturing.
5. Acquire skills in reverse engineering methodologies, from data acquisition through contact and non-contact devices to the creation of CAD models and functional prototypes.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I : INTRODUCTION	**08 Hours**
History – Development of RP systems – Applications in Product Development, Reverse	

Engineering, Rapid Tooling, Rapid Manufacturing- Principle –Fundamental – File format – Other translators – medical applications of RP – On demand manufacturing – Direct material deposition - Shape Deposition Manufacturing.	
UNIT – II: LIQUID BASED RAPID PROTOTYPING SYSTEMS	**10 Hours**
Classification – Liquid based system - Stereolithography Apparatus (SLA), details of SL process, products, Advantages, Limitations, Applications and Uses. Solid based system – Fused Deposition Modeling, principle, process, products, advantages, applications and uses - Laminated Object Manufacturing	
UNIT – III: POWDER BASED RAPID PROTOTYPING SYSTEMS	**09 Hours**
Selective Laser Sintering – principles of SLS process, principle of sinter bonding process, Laser sintering materials, products, advantages, limitations, applications and uses. Three-Dimensional Printing – process, major applications, research and development. Direct shell production casting – key strengths, process, applications and uses, case studies, research and development. Laser Sintering System, e-manufacturing using Laser sintering, customized plastic parts, customized metal parts, e-manufacturing - Laser Engineered Net Shaping (LENS).	
UNIT – IV: MATERIALS FOR RAPID PROTOTYPING SYSTEMS	**09 Hours**
Nature of material – type of material – polymers, metals, ceramics and composites liquid based materials, photo polymer development – solid based materials, powder-based materials – case study.	
UNIT – V: REVERSE ENGINEERING AND NEW TECHNOLOGIES	**09 Hours**
Introduction, measuring device- contact type and non-contact type, CAD model creation from point clouds-preprocessing, point clouds to surface model creation, medical data processing - types of medical imaging, software for making medical models, medical materials, other applications - Case study.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Illustrate the history, development, and applications of rapid prototyping systems in specific industries and contexts.
2	Examine liquid-based rapid prototyping systems, detailing their principles, processes, applications, and suitability for various design challenges.
3	Evaluate powder-based rapid prototyping systems by analyzing their principles, key applications, and performance metrics for effective manufacturing solutions.
4	Analyze materials used in rapid prototyping systems, identifying their properties, applications, and suitability through practical case studies.
5	Interpret principles and applications of reverse engineering and new technologies, assessing their impact on design processes and manufacturing efficiency.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	1	2	-	-	-	-	-	-	-	-	3	-
CO2	3	3	3	-	2	-	-	-	-	-	1	3	3

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

Textbooks:

1. Noorani, R. I. (2005). Rapid Prototyping: Principles and Applications (1st ed.). Wiley & Sons.
2. Chua, C. K., Leong, K. F., & Lim, C. S. (2003). Rapid Prototyping: Principles and Applications (2nd ed.). World Scientific Publishing Co. Pvt. Ltd.

Reference Books:

1. Pham, D. T., & Dimov, S. S. (2001). Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling (1st ed.). Springer-Verlag London Limited.
2. Liou, F. F. (2007). Rapid Prototyping and Engineering Applications (2nd ed.). CRC Press.

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PROFESSIONAL ELECTIVE IV

Automation and Control

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:	**Credits**	: 03
Hours / Week	: 03 Hours	**Total Hours**	: 45 Hours
L–T–P–S	: 3–0–0–0		

Course Learning Objectives:

This Course will enable students to:

1. Examine the architecture and components of advanced industrial automation systems, emphasizing the integration and scalability of these systems within modern industries.
2. Understand and apply advanced control strategies such as Model Predictive Control, Fuzzy Logic, and Adaptive Control to optimize industrial processes.
3. Analyze the role and implementation of various industrial communication protocols and network designs, focusing on their impact on system performance and security.
4. Assess and implement safety and regulatory standards pertinent to industrial automation, with a focus on risk management and compliance.
5. Explore emerging technologies and trends in industrial automation, evaluating their potential to enhance efficiency, sustainability, and innovation in manufacturing processes.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate theattainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information ratherthan simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible,it helps improve the students' understanding.

UNIT – I : Overview of Industrial Automation Systems	**09 Hours**

Automation Concepts and Components: Review of basic concepts in automation, emphasizing components not covered in basic courses, such as advanced sensors, actuators, and final control elements. System Architecture: Hierarchical structure of industrial automation systems including enterprise level, control level, and field level. Integration Challenges: Discussion on the integration of various automation components and systems within an existing industrial setup.

UNIT – II: Advanced Control Strategies in Automation	**09 Hours**
Advanced Control Techniques: Beyond PID—Model Predictive Control (MPC), Fuzzy Logic Control, and Adaptive Control applications in industrial settings. Real-Time Control Systems: Exploration of real-time operating systems (RTOS) in industrial automation and the implications for system design and reliability. Data-Driven Control: Introduction to the role of big data and machine learning in predictive maintenance and process optimization.	
UNIT – III: Communication Technologies in Industrial Automation	**09 Hours**
Industrial Communication Protocols: Detailed examination of protocols like EtherCAT, Modbus, PROFIBUS, and PROFINET, and their applications in industrial automation. Network Design and Security: Designing robust industrial networks and addressing cybersecurity challenges in industrial control systems. Wireless and Mobile Communications: The use of wireless sensor networks and mobile devices in monitoring and controlling industrial processes	
UNIT – IV: Safety and Regulatory Standards	**09 Hours**
Safety Standards: In-depth look at international safety standards such as ISO 13849 and IEC 62061, and how they influence the design and operation of automation systems. Regulatory Compliance: Understanding the impact of regulations on industrial automation, focusing on environmental, safety, and quality control standards. Hazard Analysis and Risk Assessment: Techniques and methodologies for assessing risks and implementing safety measures in automated environments.	
UNIT – V: Case Studies and Emerging Trends	**09 Hours**
Innovative Applications: Exploration of cutting-edge applications in industrial automation such as collaborative robots, augmented reality in maintenance, and AI-driven process control. Sustainability and Energy Efficiency: Discussion on the role of automation in enhancing energy efficiency and sustainability in manufacturing processes. Future of Industrial Automation: A look at ongoing research, potential future technologies, and their expected impact on the field of industrial automation.	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Design and evaluate the architecture of advanced industrial automation systems, demonstrating an ability to integrate various automation components effectively.
2	Apply advanced control strategies in simulated industrial scenarios, showcasing enhanced process efficiency and adaptability.
3	Develop robust communication networks for industrial automation, applying knowledge of protocols and security measures to ensure reliable and secure operations.
4	Apply international safety and regulatory standards to automation projects, ensuring compliance and prioritizing workplace safety and environmental sustainability.
5	Evaluate and incorporate emerging technologies into industrial automation systems, demonstrating foresight and innovation in tackling future challenges in automation.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	1	-	-	-	-	-	-	-	-	3
CO2	3	3	3	1	-	-	-	-	-	-	-	-	2
CO3	3	3	3	-	-	1	1	-	-	-	-	-	2
CO4	3	3	3	-	-	2	1	-	-	-	-	-	2
CO5	3	2	3	1	1	-	-	-	-	-	-	-	3

Textbooks:

1. Krutz, R. L. (2016). Industrial Automation and Control System Security Principles (2nd ed.). ISA.
2. Love, J. (2007). Process Automation Handbook: A Guide to Theory and Practice. Springer.

Reference Books:

1. Lipták, B. G. (2005). Instrument Engineers' Handbook: Process Control and Optimization (4th ed.). CRC Press.
2. Groover, M. P. (2014). Automation, Production Systems, and Computer-Integrated Manufacturing (4th ed.). Pearson.

DLI Course Mapped

AI Learning Essentials

DLI Learning Path

https://www.nvidia.com/en-in/learn/ai-learning-essentials/?utm_source

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COMPUTATIONAL TOOLS FOR THE ADDITIVE MANUFACTURING

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:	**Credits**	: 03
Hours / Week	: 03 Hours	**Total Hours**	: 45 Hours
L–T–P–S	: 3–0–0–0		

Course Learning Objectives:

This Course will enable students to:

1. Develop understanding of additive manufacturing processes, computational tools, and their industrial applications.
2. Apply CAD-based modeling and design principles specific to additive manufacturing.
3. Analyze additive manufacturing components using simulation techniques such as FEA and CFD.
4. Understand process planning, toolpath generation, and optimization of process parameters in AM.
5. Explore industrial case studies and emerging technologies including multi-material AM and AI integration.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information ratherthan simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** **-** and when that's possible,it helps improve the students' understanding.

UNIT – I : Introduction	**09 Hours**
Overview of Additive Manufacturing (AM), including major processes such as SLA, SLS, and FDM, along with applications across industries. Introduction to computational tools used in AM, including CAD, CAM, and CAE systems. Basics of 3D modeling and design considerations specific to additive manufacturing. CoE LAB: introduction to AM tools and basic 3D modeling exercises.	

UNIT – II: CAD and Design for Additive Manufacturing	09 Hours
Fundamentals of Computer-Aided Design (CAD) and use of software such as SolidWorks, AutoCAD, and Fusion 360 for creating and modifying 3D models. Design considerations specific to AM processes. Advanced design techniques including topology optimization and generative design, supported by industrial case studies. CoE LAB: CAD modeling and design optimization exercises.	
UNIT – III: Simulation and Analysis for Additive Manufacturing	**09 Hours**
Introduction to Finite Element Analysis (FEA) and its application in AM for stress, strain, and thermal analysis using tools like ANSYS and Abaqus. Basics of Computational Fluid Dynamics (CFD) and its role in simulating material flow in AM processes using tools such as Fluent and COMSOL. CoE LAB: simulation and analysis of AM components.	
UNIT – IV: Process Planning and Optimization	**09 Hours**
Process planning in AM including layer slicing, path planning, and toolpath generation using software like Materialise Magics and Simplify3D. Study of key process parameters and their impact on part quality. Techniques for process optimization using computational tools. CoE LAB: slicing, toolpath generation, and parameter optimization experiments.	
UNIT – V: Case Studies and Emerging Technologies	**09 Hours**
Industrial case studies highlighting real-world AM applications, challenges, and solutions. Exposure to expert insights through guest lectures. Study of emerging technologies such as multi-material and hybrid AM, and integration of AI and machine learning in AM. CoE LAB: case study analysis and exposure to advanced AM technologies.	

Course Outcome	Description
1	Explain additive manufacturing processes, computational tools, and their applications in various industries.
2	Apply CAD tools and design principles for developing components suitable for additive manufacturing.
3	Analyze additive manufacturing parts using simulation techniques such as FEA and CFD.
4	Apply process planning methods, including slicing, toolpath generation, and parameter optimization in AM.
5	Evaluate industrial case studies and emerging technologies such as multi-material AM and AI-driven manufacturing.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	2	-	-	-	-	-	-	-	-	1	2
CO2	3	2	3	2	3	-	-	-	2	-	1	3	3
CO3	3	3	3	2	3	-	-	-	2	-	1	3	3
CO4	3	3	3	2	3	-	-	-	2	-	1	-	3

CO5	3	3	3	2	-	-	-	-	2	-	-	-	3

Textbooks:

1. Gibson, I., Rosen, D., & Stucker, B. (2015). Additive Manufacturing Technologies: 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing. Springer.
2. Leary, M. (2019). Design for Additive Manufacturing: Developments in Plastic and Metal Printing. Elsevier.

Reference Books:

1. Zhou, K., & Yang, S. (2018). Additive Manufacturing: Materials, Processes, Quantifications and Applications. CRC Press.
2. Shah, J. J., Mäntylä, M., & Nau, D. S. (1995). Computational Methods for Design and Manufacturing. Prentice Hall

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AUTOMOTIVE ENGINEERING AND SIMULATION FUNDAMENTAL

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER- VII

Course Code	:	**Credits**	: 03
Hours/Week	: 03 Hours	**Total Hours**	: 45Hours
L–T–P–S	: **3-0-0-0**		

Course Learning Objectives:

This course will enable students to:

1. Understand the fundamentals of modern automotive engineering and vehicle development.
2. Familiarize students with the automotive product development process followed by global OEMs.
3. Introduce the principles of Computer-Aided Engineering (CAE) and simulation-driven design.
4. Explain the role of simulation in product validation, optimization, and decision-making.
5. Prepare students for careers in automotive design, simulation, and digital engineering.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of material testing of different metals and alloys

Unit-1 Introduction to Automotive Engineering	**9 Hours**
Overview of the global automotive industry, evolution of automobiles, classification of vehicles, vehicle architecture, chassis and body construction, powertrain systems, steering systems, suspension systems, braking systems, automotive safety systems,	

vehicle regulations and standards, and recent trends in automotive engineering.	
Unit-2 Automotive Product Development Process	**9 Hours**
Automotive product development lifecycle, market requirements and customer needs, concept generation, product planning, design and development, digital engineering, Product Lifecycle Management (PLM), digital mock-up, concurrent engineering, design for manufacturing, design for assembly, engineering change management, validation process, and industrial practices adopted by automotive manufacturers.	
Unit-3 Fundamentals of Automotive Simulation	**9 Hours**
Introduction to Computer-Aided Engineering, role of simulation in product development, fundamentals of the finite element method, geometry idealization, meshing concepts, material modelling, boundary conditions, structural analysis, thermal analysis, modal analysis, fatigue analysis, simulation workflow, verification and validation, interpretation of simulation results, and engineering decision-making.	
Unit-4 Simulation Applications in Automotive Engineering	**9 Hours**
Simulation-based evaluation of automotive components, structural integrity assessment, durability analysis, vibration and noise analysis, crashworthiness evaluation, occupant safety analysis, vehicle dynamics, ride and handling characteristics, lightweight design considerations, optimization techniques, virtual testing, and industrial case studies in automotive product validation.	
Unit-5 Emerging Trends in Automotive Engineering and Digital Simulation	**9 Hours**
Electric and hybrid vehicle technologies, battery systems and battery enclosure engineering, autonomous and connected vehicles, digital twin technology, artificial intelligence in automotive engineering, data-driven product development, Industry 4.0 in automotive manufacturing, sustainable mobility, future challenges in automotive simulation, and recent developments in digital engineering.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain the architecture, systems, and engineering principles of modern automobiles.
2	Describe the automotive product development process and digital engineering workflow adopted by the automotive industry.
3	Explain the principles and applications of simulation techniques used in automotive engineering.
4	Analyze the role of simulation in structural integrity, vehicle dynamics, durability, thermal performance, and crashworthiness.
5	Evaluate emerging technologies such as electric vehicles, digital twins, and AI-enabled engineering in modern automotive product development.

Table: Mapping Levels of COs to POs / PSOs													
COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	3	-	-	-	-	-	-	-	-	-	1
CO2	3	3	3	2	1	-	-	-	-	-	-	-	-
CO3	3	3	3	1	1	-	-	-	-	-	-	-	-
CO4	3	3	3	2	2	-	-	-	-	-	-	-	1
CO5	3	2	3	2	-	-	-	-	-	-	1	-	1

Suggested Text Books

1. Heisler, H., *Advanced Vehicle Technology*, Butterworth-Heinemann.
2. Gillespie, T. D., *Fundamentals of Vehicle Dynamics*, SAE International.
3. Wong, J. Y., *Theory of Ground Vehicles*, Wiley.
4. Cook, R. D., Malkus, D. S., Plesha, M. E., and Witt, R. J., *Concepts and Applications of Finite Element Analysis*, Wiley.

Reference Books

1. Dukkipati, R. V., *Vehicle Dynamics*, Narosa Publishing House.
2. Rao, S. S., *The Finite Element Method in Engineering*, Butterworth-Heinemann.
3. Moaveni, S., *Finite Element Analysis: Theory and Application with ANSYS*, Pearson.
4. SAE International, *Automotive Engineering Technical Papers*.
5. Tata Technologies Learning Resources on Automotive Product Development and Digital Engineering.

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SUSTAINABLE ENERGY MANAGEMENT AND ECONOMICS
[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the types and characteristics of various energy resources and systems
2. Explore strategies for managing energy demand and the principles behind energy pricing and market structures
3. Understand the principles and technologies used to enhance energy efficiency in various applications
4. Gain knowledge about various renewable energy technologies and their operational principles. Examine the policies and regulations that support the development and integration of renewable energy
5. Master advanced methods for the economic evaluation of energy projects, including lifecycle costing and risk analysis

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	**09 Hours**

INTRODUCTION TO ENERGY MANAGEMENT AND ECONOMICS:

Overview of energy systems and types of energy resources, Fundamentals of energy management, Basic economic principles relevant to energy, The role of energy in the global economy, Energy policies and regulations.

UNIT – II	**09 Hours**

ENERGY SUPPLY AND DEMAND MANAGEMENT: Energy supply chain and infrastructure, Factors influencing energy demand, Demand-side management and load forecasting, Energy pricing and market structures, Economic analysis of energy supply and demand.	
UNIT – III	**09 Hours**
ENERGY EFFICIENCY AND CONSERVATION: Principles of energy efficiency, Technologies and practices for improving energy efficiency. Economic analysis of energy efficiency projects, Barriers and incentives for energy conservation, Case studies on successful energy efficiency programs	
UNIT – IV	**09 Hours**
RENEWABLE ENERGY AND SUSTAINABLE DEVELOPMENT: Overview of renewable energy sources, Integration of renewable energy into the grid. Economic viability of renewable energy projects, Policy and regulatory frameworks for renewable energy, Environmental impacts and sustainability considerations.	
UNIT – V	**09 Hours**
ECONOMIC ANALYSIS AND POLICY IN ENERGY: Economic evaluation of energy projects (Cost-Benefit Analysis, Net Present Value, Internal Rate of Return), Energy policy analysis and its economic impacts, Energy market dynamics and investment strategies, Risk management in energy projects, Future trends in energy economics and policy**.**	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Analyze different types of energy resources and their roles in energy systems and the economy and also **Evaluate** the effectiveness of various energy management strategies in optimizing energy use.
2	Analyze the components and efficiency of energy supply chains and infrastructure and develop effective demand-side management strategies tailored to specific energy markets and consumer needs
3	Evaluate various technologies and practices for their potential to improve energy efficiency across different applications. Create strategies to overcome barriers to energy conservation and promote energy-saving practices.
4	Evaluate different renewable energy technologies for their operational principles, applications, and environmental impact. Develop policy recommendations that support the adoption and integration of renewable energy technologies.
5	Apply advanced methods like lifecycle costing and risk analysis to evaluate the financial viability of energy projects.

Table: Mapping Levels of COs to POs / PSOs

COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	2	2	-	-	1	-	-	-	-	-	-	2

CO2	3	2	2	-	-	1	-	-	-	-	-	-	2
CO3	3	2	2	-	-	2	-	-	-	-	-	-	2
CO4	3	2	2	-	-	3	-	-	-	-	-	-	2
CO5	3	2	2	-	-	2	-	-	-	-	-	-	2

TEXT BOOKS:

1. Frank Kreith, D. Yogi Goswami (2017), Energy Management and Conservation Handbook, CRC Press.
2. Alan P. Rossiter and Beth P. Jones (2015), Energy Management and Efficiency for the Process Industries, John Wiley & Sons

REFERENCE BOOKS:

1. Francis Vanek, Louis Albright, and Largus Angenent (2020), Energy Systems Engineering: Evaluation and Implementation, McGraw-Hill Education.
2. Charles W. Donovan (2019), Renewable Energy Finance: Powering the Future, Imperial College Press

E-Resources:

1. https://beeindia.gov.in/en
2. https://mnre.gov.in/

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COMPUTATIONAL FLUID DYNAMICS (CFD)
[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Understand the governing equations of fluid flow and their mathematical classification, including appropriate boundary conditions for incompressible flows.
2. Apply finite difference approximations to discretize partial differential equations and evaluate their consistency, stability, and convergence.
3. Solve the Navier-Stokes equations numerically for both compressible and incompressible flow problems using established algorithms.
4. Implement basic and advanced iterative methods for solving large systems of linear algebraic equations arising from CFD discretization.
5. Apply finite volume methods with structured grid generation and turbulence models to simulate engineering flows.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I Governing Equations and Mathematical Foundations	**06 Hours**

Introduction to CFD and its role in engineering analysis. Analytical calculation of fully developed flow in rectangular and triangular ducts. Derivation of equations governing fluid flow — continuity, momentum (Navier-Stokes), and energy equations. Classification of partial differential equations (elliptic, parabolic, hyperbolic). Equations for incompressible flow. Initial and boundary conditions: Dirichlet, Neumann, and mixed types. Well-posedness of problems.

VAC duct design, microfluidic channel flow, heat exchanger passage optimization, formulation of flow problems in pipes, channels, and external aerodynamics. AI-assisted derivation and verification of analytical duct flow solutions; use of symbolic computation tools to solve and simplify governing equations; automated classification of PDE types for given flow configurations.	
UNIT – II: Finite Difference Methods — Fundamentals	**08 Hours**
Basic concepts of CFD: finite difference approximations. Taylor series expansions and truncation error. Forward, backward, and central difference schemes. Higher-order approximations. Consistency, stability (von Neumann analysis), and convergence. Lax equivalence theorem. Explicit and implicit time-marching schemes. CFL condition and numerical diffusion. Numerical solution of 1D heat conduction, wave propagation, and convection-diffusion problems. AI-based error analysis and scheme selection; automated stability analysis of numerical schemes using symbolic computation; AI-assisted comparison of explicit vs. implicit scheme performance.	
UNIT – III: Solution of Navier-Stokes Equations	**09 Hours**
Solution of Navier-Stokes equations for compressible flows — explicit time-stepping methods, artificial viscosity, shock-capturing schemes. Solution of Navier-Stokes equations for incompressible flows — pressure-velocity coupling, SIMPLE and PISO algorithms, staggered and collocated grids, projection methods. Upwind differencing and numerical treatment of convection terms. Aerodynamic flow simulation, internal combustion engine intake flow, blood flow in arteries, wind loading on structures. AI-assisted selection of solution algorithms based on flow regime; machine learning-based initialization for faster convergence of iterative solvers; AI-driven flow simulation using open-source CFD solvers (OpenFOAM).	
UNIT – IV: Solution of Linear Algebraic Equations	**07 Hours**
Solution of linear algebraic equations — basic methods: Jacobi iteration, Gauss-Seidel method, Successive Over-Relaxation (SOR). Advanced methods: Conjugate gradient method, preconditioned methods, multigrid methods. Tridiagonal Matrix Algorithm (TDMA). Sparse matrix storage and computational efficiency. Convergence criteria and acceleration techniques. Efficient solution of large-scale discretized systems in industrial CFD, parallel computing considerations. AI-driven selection of optimal solvers and preconditioners based on problem characteristics; reinforcement learning for adaptive relaxation parameter tuning; AI-assisted benchmarking of solver convergence rates.	
UNIT – V: Finite Volume Method, Grid Generation, and Turbulence Modelling	**09 Hours**
Basics of the finite volume method — integral form of conservation laws, flux evaluation, control volume formulation. Structured grid generation — algebraic and elliptic methods, grid quality metrics (orthogonality, smoothness, aspect ratio). Introduction to turbulent flows — Reynolds averaging, Reynolds-Averaged Navier-Stokes (RANS) equations, closure problem. Turbulence models: mixing length model, k-ε model, k-ω model. Wall treatment and near-wall modelling.	

Industrial CFD simulation of turbulent flows in turbomachinery, automotive aerodynamics, environmental flows, and combustion systems. AI-assisted grid generation and quality assessment; machine learning-based turbulence model selection and calibration; physics-informed neural networks (PINNs) for turbulence closure.

Course Outcome	Description
At the end of the course the student will be able to:	
1	Derive the governing equations of fluid flow, classify them mathematically, and formulate boundary conditions for incompressible flow problems.
2	Construct finite difference approximations and assess their consistency, stability, and convergence properties.
3	Solve the Navier-Stokes equations for compressible and incompressible flows using pressure-velocity coupling and time-marching schemes.
4	Apply iterative solution techniques (Jacobi, Gauss-Seidel, SOR, conjugate gradient, multigrid) to solve large algebraic systems efficiently.
5	Implement finite volume discretization with structured grids and apply RANS-based turbulence models to simulate engineering flows.

Table: Mapping Levels of COs to POs / PSOs														
COs	**Program Outcomes (POs)**												**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**
CO1	3	3	3	2	3	-	-	-	-	-	-	2	1	3
CO2	3	3	3	2	3	-	-	-	-	-	-	2	1	3
CO3	3	3	3	2	3	-	-	-	-	-	-	2	1	3
CO4	3	3	3	2	3	-	-	-	-	-	-	2	1	3
CO5	3	3	3	2	3	-	-	-	-	-	-	2	1	3

Textbooks:

1. Versteeg, H. K., & Malalasekera, W. (2007). An Introduction to Computational Fluid Dynamics: The Finite Volume Method (2nd ed.). Pearson Education Ltd.
2. Ghoshdastidar, P. S. (1998). Computer Simulation of Flow and Heat Transfer. Tata McGraw Hill Publishing Company Ltd.

Reference Books:

1. Patankar, S. V. (2004). Numerical Heat Transfer and Fluid Flow. Hemisphere Publishing Corporation.
2. Chung, T. J. (2002). Computational Fluid Dynamics. Cambridge University Press.

DLI Course Mapped

Fundamentals of Accelerated Computing with CUDA Python

DLI learning path: https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-AC-02+V1&utm_source

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PROFESSIONAL ELECTIVE V

Robot Manipulators

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:	**Credits**	: 03
Hours / Week	: 03 Hours	**Total Hours**	: 45 Hours
L–T–P–S	: 3–0–0–0		

Course Learning Objectives:

This Course will enable students to:

1. Develop understanding of mechanical design principles, joint configurations, and end effector systems in robot manipulators.
2. Analyze factors affecting precision and accuracy, including error sources and compensation techniques in robotic systems.
3. Apply advanced control strategies such as nonlinear and force control methods for efficient manipulator operation.
4. Understand integration of sensors and utilize sensor feedback and fusion techniques for improved robotic performance.
5. Explore industrial applications and emerging technologies such as collaborative robots and soft robotics.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible,it helps improve the students' understanding.

UNIT – I : Advanced Manipulator Mechanics	**09 Hours**

Mechanical design of manipulators focusing on structural aspects, material selection, and performance optimization. Study of joint and link configurations such as revolute and prismatic joints and their influence on motion and workspace. Detailed analysis of grippers and end effectors, including adaptive and intelligent gripping mechanisms. CoE: design modeling and analysis of manipulator structures and end effectors.

UNIT – II: Precision and Accuracy in Robot Manipulators	09 Hours
Identification of error sources including mechanical imperfections, sensor inaccuracies, and computational limitations. Techniques for error compensation such as calibration methods and error modeling. Evaluation of performance metrics including accuracy, repeatability, and resolution in robotic systems. CoE: calibration experiments and accuracy analysis using robotic platforms.	
UNIT – III: Advanced Control of Robot Manipulators	**06 Hours**
Study of nonlinear control techniques such as feedback linearization and sliding mode control. Force control strategies including impedance and admittance control for safe and efficient interaction. Redundancy resolution methods for optimizing motion and task execution in manipulators with extra degrees of freedom. CoE: implementation of control strategies using simulation tools.	
UNIT – IV: Integration of Sensors in Manipulators	**07 Hours**
Overview of sensor types including tactile, force, and vision sensors, and their placement in manipulators. Sensor-based control using real-time feedback for adaptive operation. Sensor fusion techniques for combining multiple sensor inputs to improve accuracy and decision-making. CoE: sensor integration and real-time control experiments.	
UNIT – V: Applications and Emerging Technologies	**08 Hours**
Application of robot manipulators in industries such as automotive, electronics, and healthcare. Study of collaborative robots focusing on safety, human interaction, and control aspects. Introduction to emerging technologies including soft robotics and wearable robotic systems. CoE: exposure to industrial case studies and advanced robotic platforms.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain the mechanical design, joint configurations, and end effector systems of robot manipulators.
2	Analyze sources of errors and evaluate techniques for improving precision, accuracy, and repeatability.
3	Apply advanced control strategies, including nonlinear and force control methods, to robotic manipulators.
4	Integrate sensors and utilize sensor feedback and fusion techniques for real-time robotic control.
5	Evaluate industrial applications and emerging technologies such as collaborative robots and soft robotics.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	-	-	1	1	-	-	-	-	-	3
CO2	3	3	3	-	-	1	1	-	-	-	-	-	3
CO3	3	3	3	-	-	1	1	-	-	-	1	-	3
CO4	3	3	3	-	-	3	2	-	-	-	-	-	3
CO5	3	2	3	-	-	1	1	-	-	-	-	-	3

Textbooks:

1. Paul, R. P. (1981). Robot Manipulators: Mathematics, Programming, and Control. MIT Press.
2. Craig, J. J. (2017). Introduction to Robotics: Mechanics and Control (4th ed.). Pearson.

Reference Books:

1. Mittal, R. K., & Nagrath, I. J. (2003). Robotics and Control. Tata McGraw-Hill Education.
2. Angeles, J. (2014). Fundamentals of Robotic Mechanical Systems: Theory, Methods, and Algorithms (4th ed.). Springer.

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POWDER METALLURGY

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	: 03
Hours / Week	:	03 Hours	**Total Hours**	: 45 Hours
L–T–P–S	:	3–0–0–0		

Course Learning Objectives:

This Course will enable students to:

1. Understand the principles and fundamentals of powder metallurgy as a manufacturing process.
2. Identify the different powder metallurgy techniques and their applications in various industries.
3. Gain knowledge of the properties and characteristics of powder materials used in manufacturing processes.
4. Analyze the advantages and limitations of powder metallurgy compared to conventional manufacturing methods.
5. Develop the skills necessary to design, produce, and assess powder metallurgy components.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible,it helps improve the students' understanding.

Unit 1: Introduction to Powder Metallurgy	**08Hrs**
Overview of powder metallurgy and its historical development. Fundamentals of powder metallurgy processes. Powder characteristics and properties. Powder production methods.	
Unit 2: Powder Compaction and Shaping	**09 Hours**

Principles of powder compaction. Types of compaction presses and their operation. Tooling design for powder compaction. Post-compaction shaping techniques.	
Unit 3: Sintering and Heat Treatment	**06 Hours**
Fundamentals of sintering and its mechanisms. Sintering furnaces and atmosphere control. Sintering kinetics and densification. Heat treatment of powder metallurgy components.	
Unit 4: Secondary Operations in Powder Metallurgy	**07Hrs**
Debinding techniques for removing binders from green compacts. Post-sintering treatments (e.g., impregnation, infiltration, etc.). Finishing operations for powder metallurgy components.	
Unit 5: Powder Metallurgy Applications and Advanced Techniques	**09 Hrs**
Automotive applications of powder metallurgy components. Aerospace and defense industry applications. Powder metallurgy in biomedical and consumer goods. Metal injection molding (MIM) and its advantages. Powder forging and its application in producing high-strength components. Powder spraying and coating techniques.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply knowledge of powder characteristics and production methods to select appropriate powders for specific powder metallurgy processes.
2	Design and implement tooling for powder compaction, optimizing press types and post-compaction shaping techniques.
3	Analyze sintering mechanisms and kinetics to optimize furnace conditions and atmosphere control for enhanced densification.
4	Execute secondary operations such as debinding, post-sintering treatments, and finishing techniques to improve the quality and performance of powder metallurgy components.
5	Evaluate and integrate advanced powder metallurgy techniques like metal injection molding, powder forging, and powder spraying in various industrial applications.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	1	-	-	-	-	-	-	1	-	2
CO2	3	3	3	1	-	-	-	-	-	-	1	1	2
CO3	3	3	3	1	-	-	-	-	-	-	1	-	2
CO4	3	3	3	2	-	-	-	-	-	-	1	-	2

CO5	3	2	3	1	-	-	-	-	-	-	1	-	1

Textbooks:

1. German, R. M. (2017). Powder Metallurgy Science (4th ed.). Metal Powder Industries Federation (MPIF).
2. Cantor, B., Campbell, F. C., & Grant, P. (2014). Powder Metallurgy: Principles and Applications (1st ed.). Cambridge University Press.

Reference Books:

1. Chang, I., Zhao, Y., & Chen, M. (Eds.). (2013). Advances in Powder Metallurgy: Properties, Processing, and Applications. Woodhead Publishing.
2. Angelo, P. C., & Subramanian, R. (2008). Powder Metallurgy: Science, Technology, and Applications. PHI Learning Pvt. Ltd.

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ADVANCED ENERGY STORAGE

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER- VII

Course Code	:	**Credits**	: 03
Hours/Week	: 03 Hours	**Total Hours**	: 45Hours
L–T–P–S	: **3-0-0-0**		

Course Learning Objectives:

This course will enable students to:

1. Understand the historical evolution and current needs of energy storage, including demand variations, supply interruptions, and sustainability issues.
2. Learn about technical energy storage methods, covering potential, kinetic, thermal, chemical, electrochemical, electrostatic, and electromagnetic storage.
3. Evaluate performance factors of energy storage systems, focusing on efficiency, durability, safety, and environmental impact.
4. Compare and apply various energy storage technologies, examining their efficiency and applications in industries such as automotive and power plants.
5. Explore hydrogen fuel cells and flow batteries, including hydrogen generation, storage, and supercapacitor properties.
6. Study hybrid energy storage systems, particularly Bacitor combinations, for managing peak and continuous power needs in different applications.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods that teachers can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method but different *types of teaching methods* that may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, note-taking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain the functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher-order Thinking questions in the class.
- Adopt ***Problem-Based Learning***, which fosters students' Analytical skills, and develops thinking skills such as evaluating, generalizing, and analysing information rather than simply recalling it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the student's understanding.
- **Practical experimentation** of material testing of different metals and alloys

Unit-1	8 Hours
Storage: Historical Perspective, Introduction and Changes: Storage Needs - Variations in Energy Demand - Variations in Energy Supply - Interruptions in Energy Supply - Transmission Congestion - Demand for Portable Energy - Demand and scale requirements - Environmental and sustainability issues.	

Unit-2	7 Hours
Technical Methods of Storage: Introduction: Energy and Energy Transformations, Potential energy (pumped hydro, compressed air, springs) - Kinetic energy (mechanical flywheels) - Thermal energy without phase change passive (adobe) and active (water) - Thermal energy with phase change (ice, molten salts, steam) - Chemical energy (hydrogen, methane, gasoline, coal, oil) - Electrochemical energy (batteries, fuel cells) - Electrostatic energy (capacitors), Electromagnetic energy (superconducting magnets) - Different Types of Energy Storage Systems	

Unit-3	7 Hours
Performance Factors of Energy Storage Systems: Energy capture rate and efficiency - Discharge rate and efficiency - Dispatch ability and load flowing characteristics, scale flexibility, durability – Cycle lifetime, mass and safety – Risks of fire, explosion, toxicity - Ease of materials, recycling and recovery - Environmental consideration and recycling, Merits and demerits of different types of Storage.	

Unit-4	9 Hours
APPLICATION CONSIDERATION: Comparing Storage Technologies - Technology options- Performance factors and metrics - Efficiency of Energy Systems - Energy Recovery - Battery Storage System: Introduction with focus on Lead Acid and Lithium - Chemistry of Battery Operation, Power storage calculations, Reversible reactions, Charging patterns, Battery Management systems, System Performance, **Areas of Application of Energy Storage:** Waste heat recovery, Solar energy storage, Green house heating, Power plant applications, Drying and heating for process industries, energy storage in automotive applications in hybrid and electric vehicles.	

Unit-5	8 Hours
Hydrogen Fuel Cells and Flow Batteries: Hydrogen Economy and Generation Techniques, Storage of Hydrogen, Energy generation - Super capacitors: properties, power calculations - Operation and Design methods - Hybrid Energy Storage: Managing peak and Continuous power needs, options - Level 1: (Hybrid Power generation) Bacitor "Battery + Capacitor" Combinations: need, operation and Merits; Level 2: (Hybrid Power Generation) Bacitor + Fuel Cell or Flow Battery operation-Applications: Storage for Hybrid Electric Vehicles, Regenerative Power, capturing methods.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Analyze various energy storage needs and assess the impact of energy demand and supply variations on storage requirements.
2	Apply technical methods to design and implement different energy storage systems, including potential, kinetic, thermal, chemical, electrochemical, electrostatic, and electromagnetic storage.
3	Evaluate performance factors such as energy capture rate, discharge rate, efficiency, durability, and safety for various energy storage systems.
4	Compare and select appropriate storage technologies based on performance metrics, efficiency, and application-specific requirements in areas such as waste heat recovery, solar energy storage, and automotive applications.
5	Develop and integrate hydrogen fuel cells, flow batteries, and hybrid energy storage systems for managing peak and continuous power needs in applications like hybrid electric vehicles and regenerative power systems.

Textbooks:

1. Stolten, D. (2010). Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications. Wiley.
2. Zhang, J., Zhang, L., Liu, H., Sun, A., & Liu, R.-S. (2012). Electrochemical Technologies for Energy Storage and Conversion. John Wiley & Sons.

Reference Books:

1. Béguin, F., & Frąckowiak, E. (2013). Supercapacitors: Materials, Systems, and Applications. Wiley.
2. Doughty, D., Liaw, B. Y., Narayan, S. R., & Srinivasan, V. (2010). Batteries for Renewable Energy Storage. The Electrochemical Society.

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ENERGY SYSTEMS MODELLING AND ANALYSIS

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	2–1–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Describe fundamental principles of energy system design. Explain heat transfer mechanisms and their significance in thermal systems
2. Develop MATLAB and Simulink models for basic energy system components
3. Assess the feasibility of integrating renewable energy sources into energy systems
4. Implement control strategies to improve the performance of thermal components
5. Present a project integrating theoretical concepts with practical applications in thermal system design.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

UNIT – I	08 Hours

FUNDAMENTALS OF ENERGY SYSTEM DESIGN:

Overview of energy system design principles, Heat transfer mechanisms: conduction, convection, and radiation, Design considerations for heat exchangers, boilers, and condensers Case studies on the application of thermal system design principles

UNIT – II	08 Hours

MODELING AND SIMULATION OF ENERGY SYSTEMS:

Introduction to MATLAB and Simulink for thermal system simulation, Dynamic modeling of boilers, turbines, and heat exchangers, Simulation of transient and steady-state behavior in thermal systems. Optimization techniques for thermal system performance

UNIT – III	**08 Hours**
INTEGRATION OF RENEWABLE ENERGY SYSTEMS: Integration of solar thermal systems with boilers and heat exchangers, Modeling biomass combustion and its integration into thermal systems 'Economic analysis and lifecycle assessment of hybrid energy systems 'Case studies on successful integration of renewable energy with thermal systems	
UNIT – IV	**07 Hours**
ADVANCED TOPICS IN ENERGY SYSTEM OPTIMIZATION: Optimization algorithms for thermal energy systems, Advanced control strategies for boilers, turbines, and heat exchangers, Emerging technologies in thermal energy, such as waste heat recovery and cogeneration , Case studies on successful application of optimization and control in thermal systems	
UNIT – V	**08 Hours**
CASE STUDIES AND PROJECT IN ENERGY SYSTEM DESIGN: **Case Studies Analysis:** Detailed analysis of successful and challenging applications of energy system design principles. Examples may include retrofitting of existing systems, integration of renewable energy, and industrial applications.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Analyze fundamental principles of energy system design using governing laws of heat transfer, fluid mechanics and thermodynamics
2	Design intricate MATLAB and Simulink models to simulate and predict the behavior of complex thermal systems and propose improvements based on simulation results to optimize energy system performance.
3	Critique and justify the integration of diverse renewable energy sources into thermal systems and synthesize economic, environmental, and technical factors to propose sustainable hybrid energy solutions.
4	Develop and execute advanced optimization algorithms to maximize energy efficiency and operational performance in thermal system and formulate and implement adaptive control strategies to enhance the dynamic response and stability of thermal components.
5	Construct a comprehensive project integrating theoretical concepts with practical applications in energy system design. Justify project outcomes using systematic analysis and evidence-based reasoning

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	1	-	1	-	-	-	-	1	-	-
CO2	3	3	3	1	-	1	-	-	-	-	1	1	2
CO3	3	3	3	1	-	1	-	-	-	-	1	-	1

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

Textbooks:

1. Stoecker, W. F. (1981). Design of Thermal Systems. McGraw-Hill Education.
2. Dabney, J. B., & Harman, T. L. (2015). Mastering Simulink. Pearson.

Reference Books:

1. Lund, H. (2014). Renewable Energy Systems: A Smart Energy Systems Approach to the Choice and Modeling of 100% Renewable Solutions. Academic Press.
2. Sastry, S. S. (1988). Introductory Methods of Numerical Analysis. Prentice Hall.
3. Knopf, F. C. (2012). Modeling, Analysis, and Optimization of Process and Energy Systems. Wiley.

DLI Course Mapped
Computer-Aided Engineering (CAE)

DLI Learning Path:
https://developer.nvidia.com/topics/cae

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Reliability and maintenance in O&G Industry

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This Course will enable students:

1. To develop an understanding of the Oil and Gas industry, including upstream and downstream operations, industrial safety practices, and Health, Safety and Environment (HSE) requirements for sustainable and safe plant operation.
2. To provide knowledge of operation, inspection, and maintenance practices for static and rotating equipment using industry standards, reliability-centered maintenance principles, and equipment performance evaluation methods.
3. To introduce Non-Destructive Testing (NDT) techniques for quality inspection, defect identification, microstructural assessment, and selection of appropriate inspection methods based on material characteristics and operating conditions.
4. To enable analysis and interpretation of inspection and maintenance data through preparation of technical reports, monitoring equipment condition over time, and applying advanced inspection technologies for industrial applications.
5. To develop competency in maintenance planning and asset management, including predictive, preventive, and shutdown maintenance strategies, scheduling practices, and risk reduction approaches for improved equipment reliability and operational efficiency.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.

- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

Unit 1: Non-Destructive Examination (NDE) and Inspection Techniques	**08 Hours**
Topic: Introduction to Non-Destructive Examination (NDE) techniques used for in-service inspection of industrial equipment and components. Study of different NDE methods, the type of data and observations generated by each technique, interpretation of inspection outcomes, and selection of suitable inspection methods based on expected damage mechanisms. Overview of inspection acceptance criteria, evaluation of results, and integration of findings with applicable design and maintenance codes. **Tool Awareness:** PV Elite – Pressure Vessel and Heat Exchanger Design and Analysis **Basic Need:** To ensure equipment safety, compliance with design codes, and evaluation of mechanical strength under operating conditions. **Utilization:** Used for pressure vessel design calculations, stress analysis, nozzle load assessment, equipment life evaluation, and design verification.	
UNIT – II: Reliability Engineering for Static and Rotating Equipment	**08 Hours**
Topic: Concepts of equipment reliability and criticality assessment for static and rotating equipment. Reliability Centered Maintenance (RCM) methodology including functional analysis, functional failures, failure modes, failure effects, and failure consequence evaluation. Study of equipment performance degradation, reliability assessment, and structured maintenance planning approaches. **Tool Awareness:** CAESAR-II – Piping Stress and Flexibility Analysis **Basic Need:** To evaluate piping behavior under thermal expansion, pressure loads, and support conditions for safe operation. **Utilization:** Used for piping stress calculations, flexibility analysis, support optimization, and verification of piping system reliability.	
UNIT – III: Failure Analysis and Risk-Based Maintenance Strategies	**08 Hours**
Topic: Study of failure patterns including bathtub curve behavior, wear-out mechanisms, age-related failures, and random failures. Development of mitigation strategies through redesign, equipment upgrades, and maintenance optimization. Introduction to risk matrix concepts considering consequence and probability of failure for maintenance prioritization and asset management. **Tool Awareness:** SAP S/4HANA (Plant Maintenance Module) **Basic Need:** To manage maintenance activities systematically and improve equipment availability. **Utilization:** Used for work order management, preventive maintenance planning, maintenance history tracking, spare management, and reporting.	
UNIT – IV: Maintenance Planning, Scheduling and Shutdown Management	**08 Hours**
Topic: Principles of maintenance planning and scheduling for planned and unplanned outages. Concepts of resource allocation, maintenance sequencing, inventory planning, shutdown preparation, execution methodologies, and maintenance handbook practices for efficient equipment management and operational continuity. **Tool Awareness:** Primavera P6 for Maintenance Planning and Shutdown Scheduling **Basic Need:** To optimize maintenance timelines, allocate resources efficiently, and	

minimize downtime.

Utilization: Used for shutdown scheduling, project planning, critical path analysis, resource allocation, and maintenance execution monitoring.

UNIT – V: Maintenance Management Tools and Digital Systems	**07 Hours**
Topic: Overview of modern maintenance management tools and digital platforms used for asset and maintenance control. Introduction to enterprise maintenance systems including SAP P4/HANA and project planning concepts using Primavera P6. Understanding of data-driven maintenance practices and workflow integration for operational excellence. **Tool Awareness:** Reliability Analysis Software (ReliaSoft / Weibull Analysis Tools) **Basic Need:** To estimate equipment reliability and support data-driven maintenance decisions. **Utilization:** Used for Weibull analysis, failure trend identification, reliability modeling, MTBF calculation, and maintenance optimization	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Explain the structure of the Oil and Gas industry, including upstream and downstream operations, and demonstrate awareness of Health, Safety and Environment (HSE) practices in industrial environments.
2	Apply principles of operation, inspection, and maintenance for static and rotating equipment using reliability-centered maintenance and industry standards.
3	Select and implement suitable Non-Destructive Testing (NDT) methods for defect detection, quality evaluation, and condition assessment of engineering components.
4	Analyze inspection results, evaluate defect characteristics and equipment performance, and prepare technical reports for maintenance and operational decision-making.
5	Develop maintenance strategies including predictive, preventive, shutdown planning, and scheduling approaches to improve equipment reliability and operational efficiency.

Table: Mapping Levels of COs to POs / PSOs

COs	**Program Outcomes (POs)**											**PSOs**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**1**	**2**
CO1	3	3	3	3	3	1	-	-	-	1	2	1	3
CO2	3	3	3	3	3	1	-	-	-	1	2	1	3
CO3	3	3	3	3	3	2	-	-	-	1	2	1	3
CO4	3	3	3	3	3	1	-	-	-	1	2	1	3
CO5	3	3	3	3	3	1	-	-	-	2	2	1	3

Text Books

- R. Keith Mobley, Maintenance Engineering Handbook, McGraw-Hill Education, 8th Edition, 2019.
- John Moubray, Reliability-Centered Maintenance, Industrial Press Inc., 2nd Edition, 1997.
- J. M. Farley and Robert Higgins, Handbook of Condition Monitoring, Springer Publications, 2010.

Reference Books

- API, API Recommended Practice 580: Risk-Based Inspection, American Petroleum Institute, Latest Edition.
- API, API Recommended Practice 581: Risk-Based Inspection Technology, American Petroleum Institute, Latest Edition.

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Capstone Project Phase-1

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Course Code	:		**Credits**	:	03
Hours / Week	:	06 Hours	**Total Hours**	:	78 Hours
L–T–P–S	:	0–0–0–6			

Course Learning Objectives:

This Course will enable students to:

1. Develop the ability to identify and formulate engineering problems.
2. Apply theoretical knowledge and practical skills to design and implement engineering solutions.
3. Foster teamwork and collaborative problem-solving abilities.
4. Enhance project management and communication skills.
5. Promote innovation and creativity in addressing real-world engineering challenges.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

Content	**78 Hours**

1. **Identification of Problem Based on Literature Review:**
- Conduct a thorough literature review to identify gaps or opportunities in existing research.
- Formulate a clear problem statement based on findings.
2. **Finding the Supervisor:**
- Identify and approach faculty members with expertise in the relevant field.
- Discuss the project idea and seek guidance to finalize a supervisor.

3. **Finalizing Methodology/Design Phase:**
   - Define the research methodology, including experimental design, simulations, or theoretical analysis.
   - Develop detailed design specifications and project plan, outlining objectives, resources, and timelines.
4. **Report submission and presentation**

Course Outcome	Description
At the end of the course the student will be able to:	
1	Identify and formulate relevant engineering/research problems through systematic literature survey and gap analysis.
2	Select and justify an appropriate supervisor based on research domain, expertise, and project requirements.
3	Develop suitable research methodology, design approaches, and experimental or simulation frameworks for solving identified problems.
4	Apply AI tools, digital technologies, simulation platforms, and engineering tools to analyze and validate research outcomes.
5	Prepare and present a technically structured project report and communicate research findings effectively to academic and industrial audiences.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	-	1	-	2	1	1	3	2	2	2	2	2
CO2	1	-	1	-	1	1	1	3	3	2	2	2	2
CO3	1	-	1	-	2	1	1	2	3	2	2	2	2
CO4	1	-	1	-	2	1	1	3	3	2	2	2	2
CO5	1	-	1	-	2	1	1	3	2	2	2	2	2

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Capstone Project Phase-2

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VIII

Course Code	:		**Credits**	:	11
Hours / Week	:	22 Hours	**Total Hours**	:	286 Hours
L–T–P–S	:	0–0–0–22			

Course Learning Objectives:

This Course will enable students to:

1. Develop the ability to identify and formulate engineering problems.
2. Apply theoretical knowledge and practical skills to design and implement engineering solutions.
3. Foster teamwork and collaborative problem-solving abilities.
4. Enhance project management and communication skills.
5. Promote innovation and creativity in addressing real-world engineering challenges.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

Content	**06 ours**

1. **Execution:**
   - Implement the project plan, focusing on developing prototypes, conducting experiments, and collecting data.
   - Apply engineering principles and problem-solving techniques to address challenges and refine designs.
2. **Result Discussion:**
   - Analyze collected data to draw meaningful insights and validate the project objectives.

- Compare results with theoretical predictions and previous studies to assess the accuracy and reliability.

3. **Conclusion:**

- Summarize key findings and their implications for the field of study.
- Provide recommendations for future research or improvements based on the project's outcomes.

Course Outcome	Description
At the end of the course the student will be able to:	
1	Implement the proposed project methodology through prototype development, experimentation, simulation, and systematic data collection.
2	Apply engineering principles, AI tools, and computational techniques to solve practical project challenges and improve system performance.
3	Analyze experimental and simulation results using data analytics, machine learning, and visualization techniques to evaluate project performance.
4	Validate project outcomes by comparing results with theoretical models, existing studies, and relevant performance benchmarks.
5	Conclude the project by interpreting key findings and proposing improvements, future research directions, and potential industrial applications.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	3	3	1	-	-	-	1	2	1	3
CO2	3	3	3	3	3	1	-	-	-	1	2	1	3
CO3	3	3	3	3	3	2	-	-	-	1	2	1	3
CO4	3	3	3	3	3	1	-	-	-	1	2	1	3
CO5	3	3	3	3	3	1	-	-	-	2	2	1	3

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Research Internship/ Industry Internship

[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VIII

Course Code	:		**Credits**	:	03
Hours / week	:	06 Hours	**Total Hours**	:	78 Hours
L–T–P–S	:	0–0–06–0			

Course Learning Objectives:

This Course will enable students to:

1. Apply classroom knowledge to solve real-world engineering problems in a professional setting.
2. Develop professional skills such as teamwork, communication, and project management.
3. Gain hands-on experience with industry-specific tools, software, and equipment.
4. Understand operational structures and workflows within the mechanical engineering industry.
5. Cultivate a professional network and explore potential career paths in mechanical engineering.

Teaching-Learning Process (General Instructions)

These are sample new pedagogical methods, where teacher can use to accelerate the attainment of the various course outcomes.

- ***Lecture method*** means it includes not only traditional lecture method, but different *type of teaching methods* may be adopted to develop the course outcomes.
- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
- Show ***Video/animation*** films to explain functioning of various concepts.
- Encourage ***Collaborative*** (Group Learning) Learning in the class.
- To make ***Critical thinking***, ask at least three Higher order Thinking questions in the class.
- Adopt ***Problem Based Learning***, which fosters students' Analytical skills, develop thinking skills such as the ability to evaluate, generalize, and analyse information rather than simply recall it.
- Show the ***different ways to solve*** the same problem and encourage the students to come up with their own creative ways to solve them.
- Discuss how every ***concept can be applied to the real world*** - and when that's possible, it helps improve the students' understanding.

Content	**78 Hours**

Research Internship/Industry Internship course will be centered around experiential learning, emphasizing practical application of theoretical knowledge in a real-world setting. Students will engage in supervised projects tailored to their academic and professional interests, fostering critical thinking and problem-solving skills. Regular interactions with industry professionals through workshops, guest lectures, and mentorship will enhance their understanding of industry practices and professional etiquette. Assessments will be based on project reports, presentations, and evaluations by both faculty and industry supervisors to ensure comprehensive learning and development. This approach aims to prepare students for the workforce by developing technical skills, professional competencies, and a deep understanding of industry dynamics.

Course Outcome	Description
At the end of the course the student will be able to:	
1	Synthesize knowledge from various mechanical engineering disciplines to develop innovative solutions to complex problems encountered during the internship.
2	Evaluate and optimize engineering processes and systems within the industry setting to enhance efficiency and sustainability.
3	Formulate comprehensive reports and articulate project findings and recommendations effectively to a diverse audience, demonstrating professional communication skills.

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	2	-	-	2	1	1	3	3	2	2	2	2
CO2	1	2	-	-	2	1	1	3	3	2	2	2	2
CO3	1	2	-	-	2	1	1	3	3	2	2	2	2

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