DAYANANDA SAGAR UNIVERSITY
SCHOOL OF ENGINEERING
Devarakaggalahalli, Harohalli, Kanakapura Road, Bengaluru South District, Karnataka – 562 112

APPLIED STATISTICS & OPTIMIZATION

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

SEMESTER - III

Course Code	:		**Credits**	:	03
Hours / Week	:	03	**Total Hours**	:	45
L–T–P–J	:	3–0–0–0	**CIE+SEE**	:	60+40 Marks

Course Vision:

To develop strong mathematical and computational foundations in probability, statistical inference, numerical methods, and optimization techniques, enabling students to solve complex engineering problems and design efficient, intelligent, and AI-driven optimization systems.

Course Objectives:

This course will enable students to:

1. **Understand** the concepts of random variables and probability distributions for modelling uncertainty.
2. **Use** statistical inference methods for decision-making under uncertainty.
3. **Analyze** and solve classical optimization problems encountered in engineering applications.
4. **Develop** problem-solving skills for AI and computational systems.
5. **Apply** nonlinear optimization algorithms to solve complex real-world optimization problems.

Teaching-Learning Process (General Instructions)

Following are sample new pedagogical methods, where teachers can use to accelerate the attainment of the various course outcomes:

1. Lecture Method: Concepts, algorithms, and models are explained through structured lectures supported by Python/MATLAB demonstrations.
2. Interactive Teaching: Active learning is promoted through discussions, brainstorming, and group problem-solving activities.
3. Demonstration using Python/MATLAB: AI techniques like classification and optimization are demonstrated to visualize results and understand implementation.
4. Multimedia Learning: Videos and simulations are used to explain complex concepts and real-world applications.
5. Collaborative Learning: Students work in groups to implement projects and analyze datasets using computational tools.
6. Higher Order Thinking Questions: Analytical questions are used to develop model design, evaluation, and decision-making skills.
7. Problem-Based Learning: Real-world problems are given to apply techniques using Python/MATLAB for practical solutions.

MODULE – I	**09 Hours**

Random Variables and Probability Distributions **Topics:** Introduction to random variables, probability mass function, probability density function, distribution functions, joint probability distribution and joint density functions, marginal and conditional distributions, mathematical expectation and its properties, covariance, moment generating function, characteristic function. **Applications:** Risk analysis and financial modelling, Reliability engineering, Data analysis and forecasting, Signal processing	
MODULE – II	**09 Hours**
Inference for Decision Making **Topics:** Introduction to hypothesis, hypothesis testing procedure, p-values and decision making, test of hypothesis for proportion (single and difference of proportions), testing hypothesis about mean (Z-test and t-test), two-sample tests, test for equality of variance (F-test), Chi-Square test. **Applications:** Quality assurance and control, Clinical trials and testing, Business decision-making, Industrial process evaluation	
MODULE – III	**09 Hours**
Linear Programming **Topics:** Linear Programming: Linear programming, standard form of linear programming, geometry of linear programming problems, solution of a system of linear simultaneous equations, pivotal production of general systems of equations, graphical method, simplex algorithms, revised simplex methods, duality in linear programming. **Applications:** Resource allocation and production planning, Transportation and logistics optimization, Supply chain management, Financial portfolio optimization, Scheduling and assignment problems	
MODULE – IV	**09 Hours**
Introduction to Optimization Topics: Introduction to classical optimization, engineering applications of optimization, classification of optimization problems, single variable optimization, multivariable optimization without constraints, multivariable optimization with equality and inequality constraints, Kuhn-Tucker conditions. **Applications:** Resource allocation problems, Engineering design optimization, Production planning, Logistics and supply chain optimization	
MODULE – V	**09 Hours**
Nonlinear Optimization **Topics:** Unconstrained nonlinear optimization, univariate method, gradient of a function, gradient descent method, Fletcher-Reeves method. Constrained nonlinear optimization, characteristics of a constrained optimization problem, cutting plane method, interior and exterior penalty function methods.	

Applications: Neural network training, Portfolio optimization, Control system optimization, Engineering system design

Course Outcomes (COs)	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Apply probability concepts and random variables to analyze uncertainty	L3
2	Perform hypothesis testing and statistical inference for decision making	L3
3	Formulate and solve classical optimization problems including single and multivariable optimization with constraints.	L4
4	Develop and solve linear programming models for real-world problems	L3
5	Apply nonlinear optimization techniques such as gradient descent, Fletcher-Reeves method, and penalty methods to engineering applications.	L5

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	-	-	-	-	-

TEXT BOOKS:

1. Mendenhall, William, Robert J. Beaver, and Barbara M. Beaver. *Introduction to probability and statistics*. Cengage Learning, 2020.
2. Ross, Sheldon M. Stochastic Processes. 2nd ed., John Wiley & Sons, 1995.
3. Taha, Hamdy A. Operations Research: An Introduction. 10th ed., Pearson Education, 2017.
4. Rao, Singiresu S. Engineering Optimization: Theory and Practice. 5th ed., John Wiley & Sons, 2019.

REFERENCE BOOKS:

1. R.E. Walpole, R.H. Mayers, S.L. Mayers and K.Ye, Probability and Statistics for engineers and scientists, 9th Edition, Pearson Education, 2018.

2. Douglas A. Wolfe, Grant Schneider, Intuitive Introductory Statistics, Springer, 2017.
3. Miller & Freund's, Probability and statistics for engineers, 8th edition, Pearson publication, 2018.
4. Richard I. Levin, David S. Rubin, Masood H. Siddiqui, Sanjay Rastogi, Statistics for Management, 8th Edition, Pearson Publications, 2018.

ENGINEERING MATERIALS

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

SEMESTER – III

Course Code	:		**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	**06 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	06 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	06 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	06 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	30 HRS

[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.

FLUID MECHANICS AND MACHINERY

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

SEMESTER – III

Course Code	:		**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. **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	**06 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	**06 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,	
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	**06Hours**
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	**06 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

Mechatronics & Embedded Systems

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

III SEMESTER

Course Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	30+30
L–T–P–S	:	3–0–0–0			

Course Learning Objectives:

This course will enable students :

1. Understand the fundamentals of mechatronic systems and electronic components used in automation.
2. Study various sensors, transducers, actuators, and signal conditioning techniques.
3. Apply controllers, PLCs, and microcontrollers in mechatronic system design.
4. Understand ARM microcontroller architecture and embedded programming concepts.
5. Develop embedded and intelligent systems by interfacing sensors, actuators, and development platforms.

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 - Introduction to Mechatronics and Sensors	**09 Hours**

Introduction to mechatronics, examples of mechatronic systems, electric circuits and components, semiconductor electronics, transistor applications. Sensors and transducers: performance terminology of sensors, displacement, position and proximity sensors, force sensors, fluid pressure sensors, liquid flow sensors, temperature sensors, light sensors, acceleration and vibration measurement, semiconductor sensors, MEMS and SAW sensors.

Industrial automation systems, automotive electronics, smart sensing systems, robotics, process industries.AI-assisted sensor data acquisition, AI-based visualization

of sensor behavior, intelligent fault detection using sensor outputs.	
UNIT – II- Actuators and Signal Conditioning	**09 Hours**
Mechanical actuation systems, hydraulic and pneumatic actuation systems, electrical actuation systems, data presentation systems. Signal conditioning: introduction to signal processing and operational amplifiers, op-amp as signal conditioner, analogue to digital converter (ADC), digital to analogue converter (DAC), artificial intelligence concepts. Machine automation, process control industries, robotic systems, intelligent machines. AI-assisted actuator performance analysis, intelligent signal filtering, AI-based automation control.	
UNIT – III- Controllers and Mechatronic Design	**09Hours**
Closed-loop controllers: P, PI, PID controllers, digital controllers, programmable logic controllers (PLC), input/output and communication systems, fault finding. Design and mechatronics: projects using ATmega16 microcontroller, myoelectrically controlled robotic arm, Robocon concepts, design of legged robots. Industrial robotics, CNC machines, automated manufacturing systems, smart robotic platforms. AI-based controller tuning, intelligent robotic simulations, machine learning applications in predictive maintenance	
UNIT – IV- Embedded Systems and ARM Microcontrollers	**09 Hours**
Introduction to embedded systems and microcontrollers, instruction set architecture of ARM microcontrollers, assembly language programming. Embedded control systems, automotive electronics, consumer electronic devices, IoT systems. AI-assisted embedded coding, ARM simulation platforms, intelligent debugging systems.	
UNIT – V- Interfacing and Embedded Platforms	**09 Hours**
D/A and A/D converters, sensors, actuators and their interfacing, microcontroller development boards, embedded programming platforms. Smart embedded devices, industrial monitoring systems, automation platforms, embedded communication systems.AI-assisted interfacing simulations, intelligent hardware testing, AI-supported embedded system optimization	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Explain the fundamentals of mechatronic systems, semiconductor electronics, and sensors used in engineering applications.
2	Apply actuators, signal conditioning circuits, ADC/DAC systems, and AI concepts in automation systems.
3	Analyse control systems, PLCs, and microcontroller-based mechatronic designs for industrial applications.
4	Understand ARM microcontroller architecture and perform assembly language programming for embedded systems.
5	Interface sensors, actuators, and embedded development platforms for real-time engineering 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	-	-	2	-	1	2	-
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

Textbooks

1. W. Bolton, Mechatronics, Pearson Education.
2. Raj Kamal, Embedded Systems: Architecture, Programming and Design, McGraw Hill.
3. Nitaigour Mahalik, Mechatronics Principles, Concepts and Applications, McGraw Hill.

Reference Books

1. M. D. Singh and J. G. Joshi, Mechatronics System Design, PHI.
2. Kenneth Ayala, ARM-based Microcontrollers and Embedded Systems.
3. R. K. Rajput, A Textbook of Mechatronics, S. Chand.

DLI Course Mapped

Robotics

DLI Learning Path

https://nvdam.widen.net/s/brxsxxtskb/dli-learning-journey-2009000-r5-web#%5B%7B%22num%22%3A39%2C%22gen%22%3A0%7D%2C%7B%22name%22%3A%22XYZ%22%7D%2C0%2C1620%2C0%5D

THERMODYNAMICS

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

SEMESTER – III

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. **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	**09 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.

UNIT – II	**09 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.

UNIT – III	09 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.

UNIT – IV	09 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

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.
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.

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

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

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DATA STRUCTURES WITH C

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

SEMESTER – III

Course Code	:		**Credits**	:	02
Hours / Week	:	Hours	**Total Hours**	:	45 Hours
L–T–P–S	:	1–0–2–0			

Course Learning Objectives:

The objectives of the Course are to:

1. Introduce the fundamentals of C programming and structured problem solving for engineering applications.
2. Develop programs using arrays, functions, pointers, strings, and user-defined data types.
3. Understand linear and non-linear data structures and implement them using C.
4. Apply searching and sorting techniques to solve engineering data processing problems.
5. Develop simple data structure-based solutions for mechanical engineering applications such as inventory management, sensor data processing, manufacturing, and maintenance records

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	9 Hours

Introduction to C Programming

Introduction to Programming, Algorithms, Flowcharts, Structure of C Program, Variables, Data Types, Constants, Operators, Input and Output Functions, Decision Making Statements, Looping Statements, Functions, Storage Classes, Recursion.

UNIT – II	9 Hours

Arrays, Strings and Pointers

One-dimensional Arrays, Two-dimensional Arrays, Matrix Operations, Strings and String

Functions, Pointers, Pointer Arithmetic, Relationship between Arrays and Pointers, Dynamic Memory Allocation (malloc(), calloc(), realloc(), free()), Structures and Unions.	
UNIT – III	**9 Hours**
Linear Data Structures Introduction to Data Structures, Abstract Data Types (ADT), Time Complexity (Basic Concepts), Stack: Representation using Arrays and Linked List, Stack Operations, Applications of Stack. **Queue:** Representation using Arrays and Linked List, Circular Queue, Priority Queue, Queue Operations and Applications.	
UNIT – IV	**9 Hours**
Linked Lists Introduction to Linked Lists, Types of Linked Lists: Singly Linked List Doubly Linked List Circular Linked List **Operations:** Insertion, Deletion, Traversal, Searching.	
UNIT – V	**9 Hours**
Trees, Searching and Sorting Introduction to Trees, Binary Trees, Binary Search Tree (BST), Tree Traversals (Inorder, Preorder, Postorder), Basic Introduction to Graphs. Searching Techniques: • Linear Search • Binary Search **Sorting Techniques:** • Bubble Sort • Selection Sort • Insertion Sort • Quick Sort (Introduction)	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Develop C programs using programming fundamentals, decision-making, functions, and recursion.
2	Apply arrays, pointers, strings, structures, and dynamic memory allocation to engineering problems.
3	Implement stack and queue data structures using C for engineering applications.
4	Develop linked list-based applications for engineering data management.
5	Apply searching, sorting, and tree data structures to organize and analyze engineering datasets efficiently.

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

TEXT BOOKS

1. Reema Thareja (2024), Programming in C, 3rd Edition, Oxford University Press.
2. Ellis Horowitz, Sartaj Sahni & Susan Anderson-Freed (2019), Fundamentals of Data Structures in C, Universities Press.
3. Yashavant Kanetkar (2022), Let Us C, 17th Edition, BPB Publications.

REFERENCE BOOKS

1. E. Balagurusamy (2023), Programming in ANSI C, McGraw Hill.
2. Seymour Lipschutz (2021), Data Structures, Schaum's Outline Series, McGraw Hill.
3. Mark Allen Weiss (2018), Data Structures and Algorithm Analysis in C, Pearson.

SUSTAINABLE ENGINEERING AND ENVIROMENTAL GOVERNANCE

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

SEMESTER – III

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

Course Learning Objectives:

The objectives of the Course are to:

1. Understand sustainability concepts and ESG frameworks in engineering practice.
2. Analyse environmental impacts of engineering systems and industrial activities.
3. Evaluate sustainable design, resource efficiency, and circular economy approaches.
4. Apply ESG principles in engineering decision-making and corporate responsibility.
5. Develop solutions for sustainable development considering lifecycle, ethics, and policy aspects.

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 Sustainability and Engineering Systems	**6 Hours**

Topics: Sustainable development, triple bottom line (environmental, social, economic), global sustainability challenges, resource consumption, energy and material balance in engineering systems

Engineering Applications: Sustainable manufacturing, energy-efficient systems, resource optimization

UNIT – II Environmental Impact and Life Cycle Assessment (LCA)	**6 Hours**

Topics:

Environmental impacts (air, water, soil), pollution sources, life cycle assessment (LCA), carbon footprint, environmental indicators and metrics

Engineering Applications: Product lifecycle analysis, emission reduction strategies, sustainable product design	
UNIT – III Sustainable Materials and Circular Economy	**6 Hours**
Topics: Sustainable material selection, recycling and reuse, circular economy principles, waste minimization, green manufacturing **Engineering Applications:** Material efficiency in automotive and manufacturing, recycling systems, eco-design	
UNIT – IV ESG Frameworks and Corporate Sustainability	**6 Hours**
Topics: Introduction to ESG, environmental, social and governance pillars, sustainability reporting, corporate responsibility, regulations and policies **Engineering Applications:** Industrial sustainability practices, ESG compliance in manufacturing and energy sectors	
UNIT – V Sustainable Design, Ethics, and Future Systems	**6 Hours**
Topics: Sustainable engineering design, ethics in engineering, green technologies, renewable energy systems, smart and sustainable infrastructure **Engineering Applications:** Renewable energy systems, sustainable transportation, green buildings, smart cities	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain sustainability principles and ESG frameworks in engineering.
2	Analyse environmental impacts and resource utilization in engineering systems.
3	Apply sustainable design and circular economy concepts.
4	Evaluate ESG factors in industrial and engineering decision-making.
5	Develop sustainable and ethical engineering 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	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

Textbooks

1. Daniel A. Vallero, Fundamentals of Air Pollution, 5th Edition, Academic Press, 2014
2. Marc J. Epstein, Making Sustainability Work, 2nd Edition, Routledge, 2018.

Reference book

1. Walter Leal Filho, Sustainable Engineering: Concepts and Practices, 1st Edition, Springer, 2019
2. John Elkington, Cannibals with Forks, Reprint Edition, Capstone, 1999.

Skill Enhancement Course-I
Digital Twin

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

SEMESTER – III

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

Course Description:

The NVIDIA-DLI Certification Course on Digital Twin aims to equip students with the knowledge and practical skills required to develop, simulate, and analyze digital replicas of physical systems using advanced computational tools and GPU-accelerated platforms. The course focuses on integrating real-time data, modeling techniques, and simulation frameworks to enable predictive analysis, optimization, and intelligent decision-making in engineering applications.

Students will learn the fundamentals of digital twin technology, including system modeling, data acquisition, IoT integration, and visualization. The course emphasizes the use of modern tools such as GPU computing, AI-based simulation, and robotics integration to design and implement scalable and efficient digital twin solutions.

Course Learning Objectives:

This Course will enable students to:

1. Understand the concept and architecture of digital twins in Industry 4.0
2. Develop virtual models of physical systems for simulation and monitoring
3. Apply GPU-based computational techniques for real-time analysis
4. Integrate sensor data and IoT frameworks into digital twin environments
5. Use digital twins for predictive maintenance, optimization, and decision-making

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 Digital Twin & Industry 4.0	**06 Hours**
Fundamentals of Digital Twin, evolution from CAD to Digital Twin, Industry 4.0 concepts, cyber-physical systems (CPS), components of Digital Twin (physical entity, virtual model, data connection), applications in manufacturing, smart cities, and robotics, benefits and challenges.	
UNIT – II: System Modeling and Simulation	**06 Hours**
Mathematical modeling of physical systems, simulation techniques, discrete and continuous system modeling, multi-physics simulation basics, introduction to simulation tools, virtual prototyping, validation and verification of models.	
UNIT – III: Data Acquisition and IoT Integration	**06 Hours**
Sensors and data acquisition systems, IoT architecture, communication protocols (MQTT, HTTP), real-time data collection, edge vs cloud computing, data preprocessing, integration of IoT with Digital Twin platforms.	
UNIT – IV: GPU Computing and AI for Digital Twin	**06 Hours**
Introduction to GPU computing, parallel processing concepts, CUDA basics, role of AI/ML in Digital Twin, predictive analytics, anomaly detection, real-time simulation using GPU acceleration, case studies using NVIDIA platforms.	
UNIT – V: Applications, Visualization & Case Studies	**06 Hours**
Visualization techniques, dashboards and monitoring systems, digital twin in smart manufacturing, predictive maintenance, robotics integration, 3D visualization tools, real-time decision-making systems, industrial case studies and project discussion.	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Explain the fundamentals of Digital Twin technology, Industry 4.0 concepts, and cyber-physical systems for modern engineering applications.
2	Develop and analyze mathematical models and simulations of physical systems for creating accurate digital replicas.
3	Implement data acquisition systems and integrate IoT frameworks for real-time monitoring and communication in Digital Twin environments.
4	Apply GPU computing and AI/ML techniques *(NVIDIA-DLI Focus)* for real-time simulation, predictive analytics, and performance optimization.
5	Design and evaluate Digital Twin applications for smart manufacturing, robotics, and predictive maintenance using visualization and decision-support 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	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

DLI Course Mapped

Industrial Digital Twins Training

DLI Learning Path

https://nvdam.widen.net/s/brxsxxtskb/dli-learning-journey-2009000-r5-web

Skill Enhancement Course-I
Bosch Rexroth-Automation

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

SEMESTER – III

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

Course Description:

The **BOSCH REXROTH Certification Course in Industrial Automation** aims to provide students with comprehensive knowledge and hands-on skills in modern automation systems used in industrial environments. The course focuses on the integration of **hydraulics, pneumatics, PLC, sensors, and industrial control systems** to design, operate, and troubleshoot automated processes.

It emphasizes practical learning through **Center of Excellence (CoE) laboratories**, enabling students to gain industry-relevant exposure to real-time automation systems. The course prepares learners for smart manufacturing and Industry 4.0 applications by incorporating advanced control strategies and system integration techniques.

Course Learning Objectives:

This Course will enable students to:

1. Understand the fundamentals of industrial automation systems, control strategies, and automation hierarchy used in modern industries.
2. Gain knowledge of pneumatic and hydraulic systems, including components, circuit design, and their industrial applications # (CoE – LAB).
3. Develop understanding of sensors, actuators, and industrial drives for effective automation and system integration # (CoE – LAB).
4. Learn PLC architecture and programming techniques for controlling industrial processes and automation systems # (CoE – LAB).
5. Explore industrial automation integration using SCADA, HMI, and Industry 4.0 concepts for smart manufacturing applications # (CoE – LAB).

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 Industrial Automation	**06 Hours**
Introduction to industrial automation, automation pyramid, types of automation (fixed, programmable, flexible), basic control systems, open-loop and closed-loop systems, components of automation systems, overview of Bosch Rexroth technologies, safety standards in automation.	
UNIT – II: Pneumatics and Hydraulics Systems	**06 Hours**
Introduction to fluid power systems, properties of compressed air and hydraulic fluids, components (compressors, actuators, valves, pumps), circuit design and symbols, electro-pneumatic systems, hydraulic circuits, applications in industrial automation, troubleshooting techniques.	
UNIT – III: Sensors, Actuators and Drives	**06 Hours**
Types of sensors (proximity, pressure, temperature, flow), actuators (electric, pneumatic, hydraulic), signal conditioning, industrial drives (AC/DC motors, servo systems), selection criteria, interfacing sensors and actuators with control systems.	
UNIT – IV: Programmable Logic Controllers (PLC)	**06 Hours**
Introduction to PLC, architecture and components, programming languages (Ladder Diagram, Function Block Diagram), timers, counters, I/O modules, PLC programming for automation tasks, debugging and troubleshooting, industrial case studies.	
UNIT – V: Industrial Automation Integration & Industry 4.0	**06 Hours**
SCADA systems, HMI design, industrial communication protocols (Modbus, Profibus, Ethernet/IP), system integration, basics of IoT in automation, smart factories, predictive maintenance, real-time monitoring, case studies using Bosch Rexroth automation solutions.	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Explain the principles of industrial automation systems and their components in manufacturing environments.
2	Design and analyze pneumatic and hydraulic circuits for industrial applications
3	Select and integrate sensors, actuators, and drives for automation systems
4	Develop and implement PLC programs for controlling industrial processes
5	Apply industrial automation concepts for system integration, monitoring, and Industry 4.0 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	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

Text Books:

1. MATLAB: A Practical Introduction to Programming and Problem Solving (6th Edition) by Stormy Attaway, Elsevier.

2. MATLAB for Engineers (5th Edition) by Holly Moore, Pearson.

Reference Books:

1. Essential MATLAB for Engineers and Scientists (7th Edition) by Brian Hahn and Daniel Valentine, Academic Press.

2. MATLAB: An Introduction with Applications (6th Edition) by Amos Gilat, Wiley.

DLI Course Mapped

Fundamentals of Deep Learning

DLI Learning Path

https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3&utm_source=chatgpt.com

DIFFERENTIAL EQUATIONS & NUMERICAL METHODS

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

SEMESTER – IV

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 and apply iterative numerical methods such as Newton-Raphson and Regula-Falsi for solving algebraic and transcendental equations with emphasis on convergence and accuracy.
2. Develop the ability to solve first and higher-order differential equations using analytical methods and Laplace transforms for modelling engineering systems.
3. Learn numerical techniques such as Euler, Runge-Kutta, and multistep methods for solving ordinary differential equations, including modelling of physical systems like mass–spring systems.
4. Understand and implement numerical integration techniques such as Trapezium, Simpson's rules, and Romberg method for evaluating definite and multiple integrals.
5. Classify partial differential equations and apply finite difference methods, including Crank–Nicolson schemes, 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:	**09 Hours**

Solution of Algebraic and Transcendental Equations

Topics: Initial Approximation for an Iterative Procedure, Method of False Position, Newton-Raphson method, General Iteration Method, Convergence of Iteration Methods.

Applications: Engineering design, fluid mechanics, heat transfer, circuit analysis, population models, optimization, numerical simulations.

UNIT – II: Fourier Series	09 Hours
Differential Equations **Topics:** Introduction to First-order Ordinary Differential Equations, Linear Higher Order Differential Equations with Constant Coefficients, Homogeneous and Non-homogeneous Equations, Method of Variation of Parameters, Introduction of Laplace transforms and its properties, Solving ODE using Laplace transform. **Applications:** Electrical circuit solving, vibration analysis, control system design, heat transfer analysis, fluid flow modeling, population modeling, signal processing.	
UNIT – III: Fourier Transform	**09 Hours**
Numerical Integration **Topics:** Trapezium Rule, Simpson's 1/3 Rule, Simpson's 3/8 Rule, Romberg Method, Evaluation of Double Integrals using Trapezium Rule, Evaluation of Double Integrals by Simpson's Rule. **Applications:** Area calculation, volume estimation, heat transfer analysis, probability integrals, engineering simulations, numerical modeling.	
UNIT – IV: Numerical Methods for Solving Ordinary Differential Equations	**09 Hours**
Numerical Methods for ODE **Topics:** Euler's Method: Basic principles of Euler's method for solving first-order ODEs, Rayleigh-Ritz method, Runge-Kutta 4th order, Multistep Methods: Explanation of multistep methods (Adams-Bashforth, Adams-Moulton Methods), Second-Order ODE. Mass-Spring System (Euler Method, Runge-Kutta Methods). **Applications:** Dynamic system simulation, mass–spring analysis, population dynamics, electrical circuits, control systems, trajectory prediction.	
UNIT – V: Numerical Methods for Partial Differential Equations	**09 Hours**
Numerical Methods for PDE **Topics:** Classification of PDEs (elliptic, parabolic, hyperbolic), Finite Difference Methods (Laplace and Poisson Equations), Derivation of Finite Difference Approximations, Crank-Nicolson Method, Method for Hyperbolic PDEs. **Applications:** Heat conduction, wave propagation, fluid flow modeling, electrostatics, diffusion processes, structural analysis.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply iterative techniques to obtain approximate roots of nonlinear equations with desired accuracy.
2	Solve differential equations using classical methods and Laplace transforms for practical applications.
3	Evaluate integrals numerically using appropriate quadrature methods for engineering applications.
4	Apply numerical methods to solve initial value problems and model dynamic systems.
5	Solve PDEs numerically using finite difference methods and interpret results in physical contexts.

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	-	-	-	-	-

TEXT BOOKS:

1. Kreyszig, Erwin. Advanced Engineering Mathematics. 11th ed., Wiley, 2025.
2. Iyengar, Satteluri RK, and R. K. Jain. Numerical methods. New Age International, 2009.
3. B.S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 36th Edition, 2010.
4. Burden, Richard L., and Douglas J. Faires. Numerical analysis. PWS publishing company, 1985.

REFERENCE BOOKS:

1. Veerarajan T., Engineering Mathematics for first year, Tata McGraw-Hill, New Delhi, 2008.
2. Ramana B.V., Higher Engineering Mathematics, Tata McGraw Hill New Delhi, 11th Reprint, 2010.
3. N.P. Bali and Manish Goyal, A text book of Engineering Mathematics, Laxmi Publications, Reprint, 2010.
4. Gerald, Curtis F. Applied numerical analysis. Pearson Education India, 2004.
5. Chapra, Steven C., and Raymond P. Canale. Numerical methods for engineers. Vol. 1221. New York: Mcgraw-hill, 2011.

MECHANICS OF SOLIDS

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

SEMESTER – IV

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. 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	**09 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.	
UNIT – II Compound Stresses and Cylinders	**09 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. **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.	
UNIT – III Shear Forces and Bending Moments	**09 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. **Stress in Beams:** Bending Theory**,** Bending and shear stress distribution in rectangular,I and T section beams.	
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. **Columns:** Euler's theory, Equivalent Length, Limitations of Euler's Formula, Rankines Formula	
UNIT – V Strain Energy and Theories of Failure	**09 Hours**
Strain Energy: Strain energy due to axial, shear, bending, torsion and impact load, Castigliano's theorem and their applications. **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)	

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	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

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:

5. https://archive.nptel.ac.in/courses/105/105/105105108/
6. https://onlinecourses.nptel.ac.in/noc22_ce46/preview
7. https://www.youtube.com/watch?v=LIZ-PQbGZkA

HEAT TRANSFER

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

SEMESTER – IV

Course Code	:		**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 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	**06 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.

UNIT – II	06 Hours
Heat transfer through rectangular fin, infinitely long fin, short fin with insulated tip and without insulated tips. FIN efficiency and effectiveness. Numerical problems. **Conduction**: Lumped parameter analysis, use of transient temperature charts (Heisler's charts) for transient conduction in slab, long cylinder and sphere, numerical problems	

UNIT – III	06 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. **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.	

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.	

UNIT – V	06 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. **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).	

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	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

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

MANUFACTURING TECHNOLOGY

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

SEMESTER – IV

Course Code	:		**Credits**	:	04
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. Develop a fundamental understanding of manufacturing processes such as casting, forming, machining, and non-traditional methods, including their working principles, advantages, limitations, and industrial relevance.
2. Analyse the relationship between process parameters and product quality, including defects in casting, deformation behaviour in forming, and surface finish and accuracy in machining operations.
3. Gain practical knowledge of machine tools and machining operations such as lathe, drilling, milling, and CNC machines,
4. Understand modern manufacturing systems and automation technologies, including CNC programming, and their role in Industry 4.0 environments.
5. Apply selective AI tools and digital technologies for process analysis, defect prediction, machining optimization, and decision-making.

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' understa

UNIT – I	**06 Hours**

Casting Processes

Introduction to casting and its importance in manufacturing. Types of patterns and their allowances. Properties and types of moulding sand, sand testing methods. Steps involved in sand casting process. Solidification of metals and concept of shrinkage. Casting defects such as blow holes, porosity, shrinkage cavities, cold shuts and their remedies.

Engineering Applications:

Manufacturing of engine blocks, machine tool beds, pump housings.

UNIT – II	06 Hours

Metal Forming Processes

Concept of plastic deformation and stress-strain behaviour of materials. Hot and cold working processes. Rolling process including types of rolling mills and defects. Forging operations (open and closed die forging). Extrusion and wire drawing processes. Sheet metal operations such as blanking, punching, bending, and deep drawing.

Engineering Applications:

Production of automotive body parts, rails, structural components.

UNIT – III	06 Hours

Machining and Machine Tools

Basic principles of metal cutting, types of cutting tools and tool materials. Lathe machine operations such as turning, facing, threading, and taper turning. Drilling, milling, and shaping processes. Cutting parameters (speed, feed, depth of cut) and their influence on machining performance. Tool wear mechanisms, tool life, and use of cutting fluids.

Engineering Applications:

Manufacturing of shafts, gears, and precision components.

UNIT – IV	06 Hours

Advanced Manufacturing & Automation

Introduction to CNC machines, construction and working principles. CNC programming basics (G-codes and M-codes). Industrial robotics and their applications in manufacturing. Flexible Manufacturing Systems (FMS) and Computer Integrated Manufacturing (CIM). Concept of Industry 4.0 and smart manufacturing systems.

Engineering Applications:

Automated production lines, robotics in automobile and electronics industries.

UNIT – V	06 Hours

Non-Traditional Manufacturing Processes

Need for non-traditional machining processes. Working principles, advantages, and limitations of EDM, ECM, laser beam machining, and ultrasonic machining. Introduction to additive manufacturing (3D printing) and rapid prototyping techniques.

Engineering Applications:

Manufacturing of complex aerospace components, medical implants, and precision dies.

Sl. No	**List of Laboratory/Practical Experiments activities to be conducted (if any) Total 30 Hrs**
1	Determination of moisture content of moulding sand.
2	Determination of permeability of moulding sand.
3	Determination of green compression strength of moulding sand.
4	Preparation of sand mould using pattern.
5	Lathe operations: Turning and facing.
6	Step turning or taper turning on lathe.
7	Drilling operation using drilling machine.

8	Milling operation (slot cutting / face milling).
9	Machining flat surfaces using shaper machine.
10	Introduction to CNC machine and basic part programming.

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain the principles of casting and metal forming processes, including material behavior, process steps, and their applications in manufacturing engineering.
2	Analyze various manufacturing defects and evaluate the influence of process parameters on product quality and performance in casting and forming operations.
3	Evaluate machining processes and cutting conditions by selecting appropriate tools, materials, and parameters to achieve desired accuracy, surface finish, and productivity.
4	Understand and interpret the working principles of advanced manufacturing systems such as CNC machines, automation, and flexible manufacturing systems used in modern industries.
5	Apply AI-based tools and techniques in selected manufacturing applications such as defect prediction, machining optimization, and process monitoring,

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	-

Textbooks:

- P. N. Rao, Manufacturing Technology, McGraw-Hill.
- Kalpakjian and Schmid, Manufacturing Engineering and Technology, Pearson.

Reference Books:

- Groover, M. P., Fundamentals of Modern Manufacturing, Wiley.
- Hajra Choudhury, Elements of Workshop Technology, Media Promoters.

MACHINE LEARNING FOR MECHANICAL ENGINEERS

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

SEMESTER – IV

Course Code	:		**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 of machine learning and its relevance to mechanical engineering.
2. Apply supervised and unsupervised learning techniques to engineering datasets.
3. Develop predictive models for mechanical systems and processes.
4. Evaluate model performance and reliability using appropriate metrics.
5. Gain exposure to AI-based approaches for condition monitoring and system optimization.

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.
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- 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 Machine Learning & Data Handling	06 Hours

Introduction to AI and machine learning; types of learning; data collection; data preprocessing; feature selection; normalization; training/testing datasets. Sensor data processing, experimental data analysis, quality control. Understanding the role of data in building intelligent engineering systems.

UNIT – II- Supervised Learning – Regression	06 Hours

Linear, multiple, and polynomial regression; bias-variance tradeoff; overfitting/underfitting; error metrics (MSE, RMSE, R^2). Prediction of material properties, thermal behaviour, wear, and process outputs.Data-driven modelling of physical systems.

UNIT – III- Supervised Learning – Classification	**06 Hours**
Logistic regression, KNN, decision trees, SVM. Fault detection, defect classification, condition monitoring. Intelligent classification for decision-making in engineering systems.	
UNIT – IV- Unsupervised Learning & Feature Reduction	**06 Hours**
k-means clustering, hierarchical clustering, PCA, feature extraction. Pattern recognition in vibration data, grouping operational conditions, anomaly detection. Discovering hidden patterns in complex engineering datasets.	
UNIT – V- AI Applications in Mechanical Engineering	**06 Hours**
Topics: Predictive maintenance; introduction to neural networks; optimization using ML; concept of digital twins (introductory). • Machine health monitoring • Smart manufacturing (Industry 4.0) • Energy system optimization • Additive manufacturing process prediction • Data-driven prediction of system behaviour • Fault diagnosis using sensor data • Basic intelligent optimization approaches	

SL. No	Lab Components	30 Hrs
1	Data preprocessing and visualization using Python.	
2	Regression modelling for engineering data.	
3	Classification using KNN / Decision Tree.	
4	Clustering using k-means.	
5	PCA for dimensionality reduction.	
6	Model evaluation and validation.	
7	Case study: Fault detection dataset.	
8	Mini project on ML application in mechanical engineering.	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Explain machine learning concepts and their engineering relevance.
2	Apply regression and classification techniques to real-world datasets.
3	Use clustering and dimensionality reduction for data analysis.
4	Evaluate and interpret machine learning model performance.
5	Apply ML techniques for predictive and optimization tasks in mechanical 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	3	3	3	2	-	-	-	-	-	-	-	1	2
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CO3	2	2	2	2	-	-	-	-	-	-	-	2	1
CO4	2	2	3	3	-	-	-	-	-	-	-	1	1
CO5	3	2	3	3	-	-	-	-	-	-	-	2	2

Textbooks

1. Aurélien Géron, *Hands-On Machine Learning with Scikit-Learn & TensorFlow*
2. Tom Mitchell, *Machine Learning*

Reference Books

1. Bishop, *Pattern Recognition and Machine Learning*
2. Goodfellow et al., *Deep Learning* (Introductory)

DLI Course Mapped

Fundamentals of Deep Learning

DLI learning Path

https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3

CAD/CAM & DIGITAL VISUALIZATION
[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – IV

Course Code	:		**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. Develop 3D part modeling skills using CAD tools
2. Create assemblies and simulate mechanical systems
3. Generate CAM toolpaths and CNC programs
4. Explore generative design for optimized components
5. Apply visualization and rapid prototyping techniques

Teaching-Learning Process (General Instructions)

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- ***Interactive Teaching:*** *Adopt the* ***Active learning*** that includes brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
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- 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 Part Modeling	**06 Hours**

Practical Tasks:

- CAD interface and navigation
- 2D sketching (constraints, dimensions)
- Feature-based modeling (extrude, revolve, sweep, loft)
- Editing and parametric modifications

Engineering Applications:

Mechanical components, brackets, shafts, housings.

UNIT – II- Assembly Modeling	**06 Hours**

Practical Tasks:

- Assembly creation

- Mating conditions (coincident, concentric, etc.)
- Motion simulation
- Interference detection

Engineering Applications:
Machine assemblies, mechanisms, product systems.

UNIT – III- Introduction to CAM	**06 Hours**

Practical Tasks:
- CAM interface and setup
- Tool selection and machining parameters
- Toolpath generation (2D/3D operations)
- CNC simulation and verification
- Basic G-code understanding

Engineering Applications:
Machining of mechanical parts, CNC manufacturing.

UNIT – IV- Generative Design	**06 Hours**

Practical Tasks:
- Defining design space, loads, constraints
- Material selection
- Generative design study execution
- Interpretation of generated design options

Engineering Applications:
Lightweight structures, aerospace components.

UNIT – V- AI Digital Visualization & Rapid Prototyping	**06 Hours**

Practical Tasks:
- Rendering (materials, lighting, textures)
- Animation and exploded views
- STL file generation
- 3D printing preparation (slicing basics)

Engineering Applications:
Product presentation, rapid prototyping, design validation.

SL. No	Lab Components	30 Hrs
1	AI-assisted creation of a parametric 3D component using sketch constraints and feature-based modeling.	
2	Development of multiple components and creation of an assembly using AI-based mating and validation tools.	
3	Assembly validation followed by AI-assisted toolpath generation and CNC simulation for a selected part.	
4	Optimization of machining strategy and redesign of the component using AI-driven generative design techniques.	
5	Selection of optimized design, rendering, animation, and STL generation for 3D printing.	

Course Outcome	**Description**

At the end of the course the student will be able to:	
1	Develop parametric 3D part models
2	Create assemblies with proper constraints
3	Generate CAM toolpaths and CNC programs
4	Apply generative design for optimization
5	Perform visualization and rapid prototyping

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

3. Aurélien Géron, *Hands-On Machine Learning with Scikit-Learn & TensorFlow*
4. Tom Mitchell, *Machine Learning*

Reference Books

3. Bishop, *Pattern Recognition and Machine Learning*
4. Goodfellow et al., *Deep Learning* (Introductory)

Skill Enhancement Course-II
Generic Design – NVIDIA-DLI Certification Course

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

SEMESTER –IV

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

Course Learning Objectives:

This Course will enable students to:

1. To develop a strong foundation in engineering design thinking and problem-solving approaches.
2. To introduce modern design tools, including GPU-based simulation and AI-assisted design.
3. To enable students to model, analyze, and optimize engineering systems.
4. To promote interdisciplinary design skills applicable to robotics, digital twins, and automation.
5. To prepare students for industry-oriented design challenges using NVIDIA-DLI platforms

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.

Unit 1: Engineering Design Fundamentals and Design Thinking	**06 Hours**

Introduction to engineering design, design process and lifecycle, problem identification and requirement analysis, design thinking principles, ideation techniques, concept generation, feasibility analysis, prototyping concepts, testing and validation methods, user-centered design, case studies in engineering design .	
Module 2: Computer-Aided Design and Visualization	**06 Hours**
Introduction to CAD systems, 2D sketching fundamentals, 3D part modeling, parametric design, assembly modeling, constraints and relationships, engineering drawings and drafting standards, geometric dimensioning and tolerancing basics, visualization techniques, rendering and animation	
Module 3: Simulation and GPU-Accelerated Computing	**06 Hours**
Introduction to engineering simulation, basics of numerical methods, finite element analysis fundamentals, thermal and fluid simulation basics, boundary conditions and meshing, introduction to GPU computing, parallel processing concepts, NVIDIA GPU architecture basics, accelerated simulation workflows	
Module 4: AI-Based Design and Digital Twin Technolog	**06 Hours**
Introduction to artificial intelligence in design, machine learning basics, generative design concepts, data-driven modeling, digital twin fundamentals, real-time system monitoring, sensor data integration, predictive analytics, simulation-based decision making	
Module 5: Design Optimization and Industry Applications	**06 Hours**
Design optimization techniques, single and multi-objective optimization, parameter tuning, design for manufacturability, design for sustainability, reliability and performance analysis, applications in robotics and automation, smart manufacturing systems, autonomous systems design, capstone design project using NVIDIA-DLI tools	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply engineering design principles and design thinking methodologies to identify and solve real-world problems.
2	Develop 2D and 3D models of engineering components and assemblies using modern CAD tools.
3	Analyze engineering systems using simulation techniques and understand the role of GPU-accelerated computing in design validation.
4	Utilize AI-based tools and digital twin concepts for intelligent design and performance analysis of engineering systems.
5	Design and optimize engineering solutions considering performance, cost, and sustainability for real-world 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	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
CO5	1	1	1	2	-	-	-	2	1	-	-	-	2

Text Books

- Engineering Design: A Systematic Approach – Engineering Design: A Systematic Approach
- Product Design and Development – Product Design and Development
- Computer-Aided Design and Manufacturing – Computer-Aided Design and Manufacturing
- Digital Twin: Fundamental Concepts to Applications – Digital Twin: Fundamental Concepts to Applications

Reference Books

- Designing Digital Twins: A Problem-First Approach – Designing Digital Twins: A Problem-First Approach
- Digital Twin: Architectures, Networks, and Applications – Digital Twin: Architectures, Networks, and Applications
- Machine Learning for Engineering Design – Machine Learning for Engineering Design
- Finite Element Method: Basic Concepts and Applications – Finite Element Method

Online Reference Links

- NVIDIA Deep Learning Institute Courses
- Digital Twin Core Concepts (IIC PDF)
- Digital Twin Architectures Book (Springer)
- Digital Twin Research Overview (ScienceDirect)

DLI Course Mapped
Building Digital Twins for Physical AI With NVIDIA Omniverse

DLI Learning Path
https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-OV-04+V1

Skill Enhancement Course-II **PYTHON PROGRAMMING** [As per Choice Based Credit System (CBCS) scheme] **SEMESTER –IV**					
Course Code	:		**Credits**	:	2
Hours / Week	:	2 Hours	**Total Hours**	:	30 Hours
L–T–P–S	:	2–0–0–0			

Course Learning Objectives:

This Course will enable students to:

1. Build a strong foundation in Python programming concepts for solving engineering and computational problems.
2. Develop skills in data handling, data structures, and file operations for real-world applications.
3. Introduce scientific computing and data analysis using libraries such as NumPy, Pandas, and Matplotlib.
4. Provide fundamental knowledge of artificial intelligence and machine learning using tools like Scikit-learn.
5. Enable students to design and implement end-to-end AI-based applications using Python in a Center of Excellence (COE) environment.

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 hands-on coding sessions.*
- *Collaborative group problem-solving.*
- *Visualization and live debugging demonstrations.*
- *Problem-based learning with multiple solution approaches.*
- *Higher-order analytical problem-solving tasks.*
- *Real-world engineering application demonstrations.*

UNIT – I: Python Basics and Fundamentals	**06 Hours**
Introduction to Python programming environment (Jupyter Notebook, PyCharm, Anaconda), Python syntax and structure, variables and data types, operators, input-output operations, conditional statements, looping constructs, functions and modular programming basics, introduction to problem-solving using Python, basic AI-oriented problem formulation, COE lab exposure to Python-based tools and development environments	
UNIT – II: Data Structures in Python	**06 Hours**
Lists, tuples, sets, and dictionaries with operations and applications, data manipulation techniques, file handling concepts including reading and writing text and CSV files, data storage and retrieval, exception handling and debugging techniques, introduction to structured data for AI applications, COE-based exercises on handling real-world datasets	
UNIT – III: Scientific Computing with Python	**06 Hours**
Introduction to scientific computing, array operations using NumPy, matrix computations and broadcasting, data analysis using Pandas (Series and DataFrames), data cleaning and preprocessing techniques, data visualization using Matplotlib including 2D and 3D plots, introduction to exploratory data analysis for AI, COE lab work on real-time data analysis and visualization	
UNIT – IV: AI Foundations and Application	**06 Hours**

Development	
Introduction to artificial intelligence concepts, basic machine learning concepts using Scikit-learn, symbolic computing using SymPy, object-oriented programming concepts in Python, development of modular and reusable code, introduction to AI model building workflow, COE-based applications in robotics, automation, and intelligent systems	
UNIT – V: Capstone Project and Industry Applications	**06 Hours**
End-to-end problem solving using Python for AI applications, data collection, preprocessing, model development, and result interpretation, integration of data analysis, visualization, and basic AI models, real-world case studies in smart systems and automation, project development using COE infrastructure, project documentation, presentation, and validation of results	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Apply Python programming fundamentals to develop solutions for basic and intermediate computational problems.
2	Utilize data structures and file handling techniques to manage and process structured and unstructured data.
3	Perform data analysis and visualization using scientific computing libraries such as NumPy, Pandas, and Matplotlib.
4	Develop basic AI and machine learning applications using tools like Scikit-learn and apply object-oriented programming concepts.
5	Design and implement end-to-end Python-based solutions for real-world problems using AI techniques within a Center of Excellence (COE) environment.

Table: Mapping Levels of COs to POs / PSOs												
COs	**Program Outcomes (POs)**										**PSOs**	
COs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**1**	**1**	**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

Text Books:

- Python for Everybody: Exploring Data in Python 3 by Charles Severance, CreateSpace.
- Python Crash Course (2nd Edition) by Eric Matthes, No Starch Press.

Reference Books:

- Automate the Boring Stuff with Python (2nd Edition) by Al Sweigart, No Starch Press.
- Learning Python (5th Edition) by Mark Lutz, O'Reilly Media.

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

RESPONSIBLE AI, ETHICS & POLICY
[As per Choice Based Credit System (CBCS) scheme]
SEMESTER - V

Course Code	:	26AM35XX	**Credits**	:	02
Hours / Week	:	02	**Total Hours**	:	30
L–T–P–J	:	2–0–0–0	**CIE+SEE**	:	60+40 Marks

Course Objectives:
This course will enable students to:

6. Understand ethical frameworks and principles relevant to the design and deployment of artificial intelligence technologies.
7. Analyze the societal, legal, and policy implications of AI adoption across different sectors.
8. Apply the principles of Responsible AI in the development and evaluation of AI systems.
9. Evaluate and design AI solutions that are ethical, transparent, and socially responsible.
10. Design responsible AI strategies and governance mechanisms aligned with global standards and regulatory frameworks.

Teaching-Learning Process (General Instructions)

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

1. **Lecture method** along with traditional lecture method, different type of teaching methods may be adopted to develop the course outcomes.
2. **Interactive Teaching:** incorporating brainstorming, discussing, group work, focused listening, formulating questions, notetaking, annotating, and roleplaying.
3. Encourage **Collaborative** (Group Learning) Learning in the class.
4. To make **Critical thinking**, asking higher order thinking questions in the class in the form of Quiz and writing programs with complex solutions.
5. Showing the **different ways to solve** the same problem and encourage the students to come up with their own creative ways to solve them.

MODULE – I	**06 Hours**

Foundation of Responsible and Authentic Intelligence

Topics: Concept of Responsible AI and Authentic Intelligence, Principles of Authentic Intelligence, Human-centred AI, trust, transparency, fairness, accountability, and inclusivity and its societal impact, Ethical frameworks for AI, Human values and cultural contexts in AI systems.

Applications: Ethical decision-making in AI-powered recommendation systems, Responsible deployment of AI assistants and chatbots.

MODULE – II	**06 Hours**

Bias, Fairness, Transparency and Human-Aligned AI

Topics: Sources of bias in AI, data bias, algorithmic bias, societal bias, Fairness metrics and bias mitigation techniques, Algorithmic transparency and explainability, Explainable AI (XAI) models and interpretability methods.

Applications: Transparent AI decision systems in government services, Bias detection in hiring and recruitment AI systems.

MODULE – III	06 Hours
Privacy, Safety and Trustworthy AI Systems **Topics:** Privacy challenges in AI-driven systems, Privacy-preserving machine learning, differential privacy, federated learning, AI security risks and adversarial attacks, Robustness, safety, and reliability of AI models, Trustworthy AI lifecycle frameworks. **Applications:** Privacy-preserving healthcare analytics, Secure AI-based financial fraud detection systems, autonomous vehicles.	
MODULE – IV	**06 Hours**
AI Governance, Regulation and Responsible Innovation **Topics:** AI governance and regulatory frameworks, Algorithmic accountability and auditing mechanisms, AI risk assessment and impact evaluation models, Global AI policy initiatives and standards, responsible innovation in AI development. **Applications:** AI compliance frameworks in organizations, Ethical review boards for AI systems.	
MODULE – V	**06 Hours**
Designing Authentic and Responsible AI Systems **Topics:** Human-centered AI design methodologies, Responsible AI development lifecycle, Social and economic implications of emerging AI technologies, Sustainable and inclusive AI development. **Applications:** Responsible design of generative AI systems, AI solutions for social good, AI deployment in smart cities and governance.	

Course Outcomes (COs)	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
1	Explain key concepts and principles of Responsible AI, including fairness, transparency, accountability, and privacy	L2
2	Analyze ethical challenges and societal impacts associated with AI technologies	L4
3	Evaluate AI systems for bias, reliability, and ethical risks using appropriate frameworks	L5
4	Interpret AI governance models, regulatory guidelines, and policy frameworks related to responsible AI for ethical governance	L3
5	Apply responsible AI principles in the design and development of trustworthy AI solutions	L4

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

TEXT BOOKS:

1. M. Coeckelbergh - AI ethics, 2020, MIT press, ISBN: 978-0262538190.
2. S. Agarwal & S. Mishra - Responsible AI Implementing Ethical and Unbiased Algorithms, 2021, Springer, https://doi.org/10.1007/978-3-030-76860-7.

REFERENCE BOOKS:

1. S. Voeneky, P. Kellmeyer, O. Mueller, and W. Burgard - The Cambridge handbook of responsible artificial intelligence: interdisciplinary perspectives, eds., 2022, Cambridge University Press, ISBN: 9781009207867 / 9781009207898, DOI: 10.1017/9781009207898.

Smart Manufacturing and Digital Twins

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

V SEMESTER

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. Understand the evolution from conventional manufacturing to smart manufacturing, Industry 4.0, and Industry 5.0.
2. Explain the role of sensors, PLCs, SCADA, IIoT, cyber-physical systems, cloud/edge platforms, and manufacturing data pipelines.
3. Apply artificial intelligence and machine learning tools for process monitoring, quality inspection, predictive maintenance, and production optimization.
4. Develop conceptual and simulation-based digital twin models for machines, processes, production lines, and manufacturing assets.
5. Evaluate smart manufacturing solutions using technical, economic, safety, sustainability, cybersecurity, and ethical criteria.

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 - Fundamentals of Smart Manufacturing and Industry 4.0	**09 Hours**

Topics: Evolution of manufacturing systems: conventional manufacturing, automation, CIM, FMS, lean manufacturing, agile manufacturing, digital manufacturing, smart manufacturing. Industry 4.0 and Industry 5.0 concepts. Cyber-physical systems (CPS),

smart factory architecture, horizontal and vertical integration, product lifecycle data, manufacturing execution systems (MES), enterprise resource planning (ERP), smart supply chains, and digital thread.	
UNIT – II- Sensors, Automation, PLC/SCADA and Industrial IoT	**09 Hours**
Industrial sensors and actuators; proximity, photoelectric, pressure, temperature, vibration, current, torque, encoder and vision sensors. Data acquisition systems, signal conditioning, sampling, noise, calibration. PLC fundamentals, ladder logic, SCADA, HMI, industrial communication protocols, OPC UA, MQTT, Modbus, Ethernet/IP, edge devices, cloud connectivity, and basic cybersecurity for industrial systems.	
UNIT – III- AI, Machine Learning and Data Analytics for Manufacturing	**09 Hours**
Manufacturing data lifecycle: data generation, storage, preprocessing, labelling, feature extraction, visualization, and model validation. Introduction to AI/ML for mechanical engineers: regression, classification, clustering, decision trees, random forests, neural networks, anomaly detection, time-series forecasting, and computer vision. Quality prediction, defect detection, tool wear monitoring, process parameter optimization, and predictive maintenance. Basics of explainable AI, uncertainty, bias, and responsible AI.	
UNIT – IV- Digital Twin Concepts, Modelling and Validation	**09 Hours**
Definitions and classification of digital twins: product twin, process twin, production twin, and performance twin. Digital twin architecture: physical asset, virtual model, data connection, analytics layer, visualization layer, and decision layer. Model types: physics-based models, data-driven models, hybrid models, discrete-event simulation, finite element/simulation models, system dynamics, and reduced-order models. Digital thread, real-time synchronization, calibration, verification, validation, and uncertainty. Virtual commissioning, what-if analysis, and lifecycle management.	
UNIT – V- Smart Factory Implementation, Sustainability and Human-Centric Manufacturing	**09 Hours**
Smart manufacturing implementation roadmap, maturity models, system integration, MES/ERP connectivity, production scheduling, robotics and cobots, additive manufacturing integration, augmented/virtual reality in manufacturing, digital work instructions, cybersecurity, data governance, safety, ethics, and human-machine collaboration. Sustainable smart manufacturing: energy analytics, waste reduction, lifecycle thinking, circular manufacturing, green manufacturing, and Industry 5.0 human-centricity.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain the principles of smart manufacturing, Industry 4.0/5.0, cyber-physical systems, and digital transformation in manufacturing.
2	Identify and integrate sensors, actuators, PLC/SCADA, IIoT communication protocols, and data acquisition systems for smart factory applications.
3	Apply AI/ML and data analytics techniques for manufacturing quality control, process prediction, anomaly detection, and predictive maintenance.

4	Develop and validate basic digital twin models for manufacturing equipment, processes, and production systems using simulation and real-time data.
5	Evaluate smart manufacturing and digital twin solutions with respect to productivity, reliability, sustainability, human factors, cybersecurity, and responsible AI use.

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

Textbooks

- Groover, M. P., Automation, Production Systems, and Computer-Integrated Manufacturing, Pearson.
- Groover, M. P., Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, Wiley.
- Koren, Y., The Global Manufacturing Revolution: Product-Process-Business Integration and Reconfigurable Systems, Wiley.
- Tao, F., Zhang, M., and Nee, A. Y. C., Digital Twin Driven Smart Manufacturing, Academic Press.

Reference Books

- Chryssolouris, G., Manufacturing Systems: Theory and Practice, Springer.
- Alpaydin, E., Introduction to Machine Learning, MIT Press.
- Provost, F. and Fawcett, T., Data Science for Business, O'Reilly.
- Ustundag, A. and Cevikcan, E. (Eds.), Industry 4.0: Managing The Digital Transformation, Springer.

KINEMATICS AND DYNAMICS OF MACHINES

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

SEMESTER – V

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

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	06 Hours

BASICS OF MECHANISMS

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

Inversions of various mechanism. Quick return motion Mechanisms.

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

UNIT – II KINEMATIC ANALYSIS	06 Hours

KINEMATIC ANALYSIS

Velocity and acceleration analysis of Four Bar mechanism, slider crank mechanism. Relative velocity and acceleration of particles in a common link and coincident Particles on separate links- Coriolis component of acceleration. Velocity Analysis by Instantaneous Center Method. Klein's Construction: Analysis of velocity and acceleration of single slider crank mechanism.	
UNIT – III STATIC AND DYNAMIC FORCE ANALYSIS	**06 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. Dynamic Force Analysis: D'Alembert's principle, inertia force and torque. Dynamic force analysis of four-bar and slider crank mechanism.	
UNIT – IV BALANCING OF ROTATING AND RECIPROCATING MASSES	**06 Hours**
BALANCING OF ROTATING AND RECIPROCATING MASSES Static and dynamic balancing. Balancing of single and several rotating mass. Balancing of single cylinder engine: multi cylinder-inline engine (primary & secondary forces), V-type engine. Balancing of locomotives	
UNIT – V CAMS, GOVERNORS, AND GYROSCOPE	**6 Hours**
CAMS, GOVERNORS, AND GYROSCOPE Types of cams and followers. Development of cam profile for various types of followers and its different motion. Governors: Types of governors; governor characteristics, force analysis of centrifugal governors. Gyroscope: Vector representation of angular motion. Gyroscopic couple, effect of gyroscopic couple on ship, plane disc, aeroplane.	
	30 HRS
• Study and verify the inversions of four-bar, slider-crank, and double-slider-crank mechanisms using a kinematic model. • Construct and analyze quick-return, straight-line, intermittent-motion, pantograph, and steering mechanisms. • Perform velocity and acceleration analysis of a four-bar mechanism using graphical and analytical methods. • Determine velocity and acceleration of a slider-crank mechanism using relative velocity, instantaneous center, and klein's construction methods. • Perform static force analysis of a four-bar or slider-crank mechanism using free-body diagrams and the principle of virtual work. • Perform dynamic force analysis of a four-bar and slider-crank mechanism using d'alembert's principle. • Experimentally verify static and dynamic balancing of rotating masses using a balancing machine or simulation. • Analyze the balancing of single-cylinder and multi-cylinder engines considering primary and secondary unbalanced forces. • Construct cam profiles for different followers using uniform velocity, shm, and cycloidal motion laws. • Determine the characteristics of centrifugal governors and analyze gyroscopic couple and its effects using experimental/simulation methods.	

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	-

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.

FINITE ELEMENT METHOD

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

SEMESTER – V

Course Code	:		**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. Apply the basic principles of FEM, discretization, and numerical modelling in engineering analysis.
2. Formulate element equations for 1D structural problems using stiffness matrices, load vectors, and coordinate transformations.
3. Assemble global equations using connectivity, boundary conditions, and system matrices.
4. Analyze stresses, strains, displacements, and convergence behavior in finite element results.
5. Evaluate FEM solutions using computational tools and validate results through convergence and accuracy assessment.

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 Introduction to FEM and Variational Concepts	**06 Hours**

Engineering analysis, discretization, nodal approximation, shape functions, interpolation, weak form, energy methods, and overview of finite element workflow.

Structural members, heat transfer elements, and simple mechanical components. AI-assisted explanation of weak form derivation, automatic summarization of FEM steps, and AI-based

checking of modelling assumptions.	
UNIT – II 1D Elements and Assembly	**06 Hours**
Bar and truss elements, element stiffness matrix, load vector, coordinate transformation, element connectivity and preliminary assembly concepts. Axial members, trusses, tie rods, and lattice structures. AI-supported derivation checks for element matrices, step-by-step assembly validation, and comparison of AI-generated and manual solutions.	
UNIT – III Beam and Frame Elements	**06 Hours**
Beam bending basics, frame element formulation, nodal degrees of freedom, consistent loading, and computation of displacement and internal forces. Beams, frames, machine supports, and simple civil/mechanical load-carrying members. AI-guided bending analysis, automated consistency checking of sign conventions, and model debugging using generated code snippets.	
UNIT – IV 2D Elements and Stress Analysis	**06Hours**
Plane stress and plane strain, triangular and quadrilateral elements, serendipity, numerical integration, stress recovery, and introduction to mesh quality. Plates, brackets, joints, and thin mechanical parts. AI-assisted element selection, mesh comparison, and automated interpretation of contour plots for stress concentration.	
UNIT – V FEM Practice, Verification, and Convergence	**06 Hours**
Error estimation, mesh refinement, convergence, post-processing, basic thermal analogy, and an introduction to commercial finite element tools. Component verification, design checks, and failure screening. AI-based result validation, convergence trend prediction, and debugging of input files or code with human judgment.	

List of Laboratory/Practical Experiments activities to be conducted (if any) :30 Hrs	
1.	Solution of a 1D bar element problem- min 2 experiments.
2.	Truss analysis using element assembly and boundary conditions- min 2 experiments.
3.	Beam bending problem using finite element formulation – min 2 experiments.
4	Stress analysis of a simple bracket using FEM software.
5	Mesh refinement study for displacement and stress convergence.
6	Use AI tools to verify derivations of stiffness matrices.
7	Perform AI-assisted code debugging for assembly and boundary conditions.
8	Compare AI-generated contour plots with manual/analytical verification.

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Apply FEM concepts such as discretization, interpolation functions, weak form, and variational principles.
2	Formulate element matrices for bars and trusses, including stiffness matrices, load vectors, and coordinate transformation.
3	Assemble global system equations and apply essential and natural boundary conditions for beam and frame elements.

4	Analyse stress, strain, and deformation results for 2D elements under plane stress and plane strain conditions.
5	Evaluate FEM software or coded routines to verify solutions, judge convergence behaviour, and assess solution accuracy.

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

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.

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+S-AC-10+V1

CONTROL SYSTEMS & DIGITAL TWIN

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

SEMESTER – V

Course Code	:		**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. Model engineering systems using transfer functions and block diagrams.
2. Analyze time response, steady-state error, and stability of control systems.
3. Analyze control system behaviour using root-locus and frequency-response methods.
4. Design basic compensators and PID controllers for engineering applications.
5. Develop and interpret state-space and digital control models using modern tools.

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 Introduction and Modelling	**06 Hours**
Topics: Open-loop and closed-loop systems, feedback concept, mathematical modelling, transfer functions, block diagrams, and signal-flow representation. Engineering Applications: Position control, speed control, temperature control, and actuator systems.	

UNIT – II-Time Response and Error Analysis	**06 Hours**
Topics: Standard input responses, first-order and second-order systems, transient response specifications, steady-state error, and system type. Engineering Applications: Servo mechanisms, mechanical drives, and simple automation systems.	

UNIT – III Stability Analysis	06 Hours
Topics: Stability concept, characteristic equation, Routh-Hurwitz criterion, root-locus basics, pole-zero interpretation, and gain effects. Engineering Applications: Mechanical actuators, process loops, and damping-related control problems.	
UNIT – IV Frequency Response and Compensators	**06 Hours**
Topics: Polar plots, Bode plots, Nyquist basics, gain margin, phase margin, lead-lag compensation, and PID control. Engineering Applications: Speed regulation, vibration isolation, and process tuning.	
UNIT – V Module 5: State Space and Digital Control Basics	**06 Hours**
Topics: State variables, state-space representation, controllability, observability, sampled-data idea, and introduction to discrete control. Engineering Applications: Mechatronic systems, intelligent actuators, and computer-based control.	
Lab Component	**30 Hrs**
• Develop and simulate open-loop and closed-loop control systems in MATLAB using transfer functions and feedback blocks. • Model a mechanical position or speed control system in MATLAB and obtain its transfer function and block-diagram representation. • Analyze first-order and second-order systems in MATLAB and determine their transient response specifications for standard inputs. • Calculate and plot the steady-state error and system type of a control system in MATLAB for step, ramp, and parabolic inputs. • Determine system stability using the Routh-Hurwitz criterion and verify the results through MATLAB pole analysis. • Plot the root locus of a control system in MATLAB and study the effect of gain variation on system stability and pole locations. • Generate Bode and Nyquist plots in MATLAB and determine gain margin, phase margin, and system stability. • Design and analyze lead, lag, and lead-lag compensators in MATLAB to improve the performance of a given control system. • Design and tune a PID controller in MATLAB for a mechanical/process control system and compare its transient and steady-state performance. • Develop a state-space model in MATLAB and analyze controllability, observability, and basic digital control response of a mechatronic system.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Model engineering systems using transfer functions, block diagrams, and signal-flow graphs.
2	Analyze transient and steady-state response of first- and second-order systems.
3	Analyze stability of control systems using Routh criterion, root locus, and pole-zero concepts.
4	Design compensators and PID controllers using frequency-response methods.
5	Develop and interpret state-space and digital control models using simulation and AI-assisted 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	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	2	3	3	3	3	3

Textbooks

1. Control Systems Engineering by I. J. Nagrath and M. Gopal, 5th Edition, 2007, New Age International
2. Modern Control Engineering by Katsuhiko Ogata, 5th Edition, 2010, Pearson
3. Modern Control Systems by Richard C. Dorf and Robert H. Bishop, 13th Edition, 2016, Pearson

Reference Books

1. Discrete-Time Control Systems by Katsuhiko Ogata, 2nd Edition, 1995, Pearson
2. Feedback Control of Dynamic Systems by Gene F. Franklin, J. David Powell, Abbas Emami-Naeini, 7th Edition, 2015, Pearson

DLI Course Mapped (15 Hrs)

Building Digital Twins for Physical AI With NVIDIA Omniverse

DLI learning path

Getting Started With

https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-OV-04+V1

PROFESSIONAL ELECTIVE-1

Sensors & Actuators

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

SEMESTER – V

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 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	**09 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	**09 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	**09 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**	**1**	**1**	**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

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.

AUTOMATED MANUFACTURING SYSTEMS

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

SEMESTER – V

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 automated manufacturing systems, their components, and the role of automation in modern industries.
2. Understand industrial robotics, including robot configurations, programming, integration, and safety practices.
3. Analyze concepts of Computer-Integrated Manufacturing (CIM) and its integration with enterprise systems such as CAD, CAM, ERP, and MES.
4. Apply principles of automated material handling systems for efficient design and implementation in manufacturing environments.
5. Understand quality control techniques, including automated inspection, sensor-based monitoring, and statistical process control in automated 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 Automated manufacturing Systems	**09 Hours**
Overview of manufacturing systems, including evolution and different types of automation. Study of key components such as machines, control systems, and information flow. Role of automation in improving productivity and efficiency, along with its economic and strategic importance in modern industries. CoE LAB: exposure to automated system layouts and basic manufacturing simulations.	
UNIT – II: Industrial Robotics and Automation	**09 Hours**

Fundamentals of industrial robotics, robot configurations, and applications in manufacturing. Study of robotic work cells and system integration. Basics of robot programming and control, along with safety standards and maintenance practices. CoE LAB: robot programming, work cell setup, and safety demonstrations.

UNIT – III: Computer-Integrated Manufacturing (CIM)	09 Hours
Concept of CIM and its role in integrating manufacturing processes. Study of key components such as CAD, CAM, and CAPP, along with CIM architecture and data flow. Integration with enterprise systems like ERP and MES, including benefits, challenges, and industrial case studies. CoE LAB: CIM workflow simulation and CAD-CAM integration exercises.	

UNIT – IV: Automated Material Handling Systems	09 Hours
Overview of material handling systems including conveyors, AGVs, AS/RS, and industrial trucks. Design principles and implementation strategies for efficient material movement. Industrial applications and case studies. CoE LAB: demonstration of automated handling systems and layout planning.	

UNIT – V: Quality Control and Monitoring in Automated Systems	09 Hours
Principles of quality control in automated manufacturing. Study of automated inspection and testing techniques using sensors and data acquisition systems. Introduction to statistical process control (SPC) and quality management systems (QMS). CoE LAB: quality analysis, SPC tools, and inspection system demonstrations.	

Course Outcome	Description
1	Explain the fundamentals of automated manufacturing systems, including components, types of automation, and their industrial significance.
2	Analyze industrial robotic systems, including configurations, programming, integration, and safety requirements.
3	Apply concepts of Computer-Integrated Manufacturing (CIM) and evaluate the integration of CAD, CAM, ERP, and MES systems.
4	Analyze and select appropriate automated material handling systems such as conveyors, AGVs, and AS/RS for manufacturing applications.
5	Evaluate quality control methods, including automated inspection, sensor-based monitoring, and statistical process control in automated environments.

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	-	-	-	-	-	-	-	-

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.

INTRODUCTION TO HYBRID & ELECTRIC VEHICLES

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

SEMESTER – V

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. 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	**09 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	**09 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	**09 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

TEXT BOOKS:

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

ADVANCED SOLID MECHANICS

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

SEMESTER – V

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. Review stress and strain concepts in three dimensions and apply transformation ideas.
2. Analyse combined loading, torsion, and pressure-vessel problems.
3. Understand failure theories, energy methods, and stability concepts.
4. Introduce fracture, fatigue, and stress concentration at an introductory UG level.
5. Use AI tools to check derivations, visualise fields, and validate results.

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 : Three-Dimensional Stress and Strain	**09 Hours**
Stress tensor idea, strain tensor idea, stress transformation, principal stresses, principal strains, and invariants at an introductory level. Shafts, pressure parts, joints, and machine components. AI-assisted tensor visualization, concept checks, and quick comparison of transformed stress values.	
UNIT – II: Combined Loading and Torsion	**09 Hours**
Combined bending, axial load, and torsion; shear stress in circular shafts; thin and thick cylinder basics. Transmission shafts, pressure vessels, and rotating parts. AI-supported formula selection, stress calculation checks, and automated comparison of loading cases.	
UNIT – III: Strain Energy and Energy Methods	**09 Hours**

Strain energy in axial, bending, shear, and torsion loading; Castigliano idea; unit-load method basics; and deflection estimation. Deflection checks, machine parts, and structural members. AI-assisted derivation guidance, step checking, and verification of displacement results.	
UNIT – IV: Failure Theories and Stability	**09 Hours**
Maximum normal stress, maximum shear stress, distortion energy, Mohr-based interpretation for failure, column buckling basics, and slenderness effects. Design checks for shafts, columns, brackets, and frames. AI comparison of failure criteria, stability diagnosis, and interpretation of safe versus unsafe states.	
UNIT – V: Stress Concentration, Fatigue, and Fracture Basics	**09 Hours**
Notches and stress concentration, S-N curve concept, fatigue loading, endurance idea, and an introduction to crack growth and fracture toughness, Basic numerical estimation of fatigue life (introductory level). Welded joints, rotating components, and cyclically loaded parts. AI-assisted life estimation discussion, defect screening, and summary of fatigue trends.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain three-dimensional stress and strain concepts, tensor representation, and stress transformation.
2	Analyse combined loading, torsion, and pressure vessel problems.
3	Apply strain energy methods (Castigliano/unit-load) for deformation analysis.
4	Apply failure theories and stability concepts for design evaluation of components.
5	Analyse stress concentration, fatigue, and basic fracture behaviour of mechanical components and validate results using analytical and AI-assisted methods.

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

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

Smart Production systems (AR/VR-Lab)

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

SEMESTER – V

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 to:

1. Understand fundamentals of augmented reality and its integration with automation systems.
2. Analyse AR hardware, software, and tracking technologies.
3. Study AR applications in manufacturing, maintenance, and training systems.
4. Evaluate AR-based human–machine interaction and industrial use cases.
5. Develop AR-enabled automation solutions using modern tools and AI techniques.

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 Augmented Reality	09 Hours

Introduction to augmented reality, virtual reality and mixed reality, AR system components, AR hardware devices (HMDs, smart glasses, sensors), AR software architecture, coordinate systems and transformations, display technologies, calibration and registration techniques.
AR-based visualisation in manufacturing systems, digital overlays for machine operations, and industrial training environments. AI-assisted object recognition, scene understanding, and AR environment mapping.

UNIT – II: Tracking, Sensing and Visualisation	09 Hours

Tracking technologies (marker-based, markerless, sensor-based), computer vision fundamentals, feature detection and matching, SLAM (Simultaneous Localisation and Mapping), depth sensing, rendering techniques, 3D visualisation, and real-time data integration.
AR-guided assembly, real-time monitoring of machines, navigation in industrial environments. Machine learning for object tracking, AI-based pose estimation and environment modelling.

UNIT – III: AR in Manufacturing and Automation	**09 Hours**
AR in production systems, assembly assistance, maintenance and repair systems, human-machine interaction, AR in robotics and automation, integration with IoT and cyber-physical systems, digital twins and smart factories. AR-assisted maintenance, remote troubleshooting, robotic guidance systems, smart manufacturing environments. Predictive maintenance using AR interfaces, AI-based decision support systems.	
UNIT – IV: AR System Development and Implementation	**09 Hours**
AR development platforms (Unity, Vuforia, ARCore, ARKit), interface design, user interaction techniques, system integration, cloud-based AR, performance optimization, usability and ergonomics, safety considerations. Development of AR-based industrial applications, training simulators, and inspection systems. AI-driven user interaction, gesture recognition, and adaptive AR systems.	
UNIT – V: Advanced Applications and Future Trends	**09 Hours**
Advanced AR systems, collaborative AR, industrial metaverse, AR in quality inspection, AR for remote operations, Industry 4.0 integration, challenges and limitations, and ethical considerations. Smart factories, remote industrial operations, quality control and inspection systems. Integration of AR with digital twins, AI-based optimisation and real-time analytics.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain principles and components of augmented reality systems.
2	Analyse AR tracking, visualisation, and interaction techniques.
3	Evaluate AR applications in industrial automation.
4	Apply AR tools for simulation and system design.
5	Develop AR-based solutions for smart manufacturing environments.

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

Textbooks

1. Schmalstieg & Hollerer – Augmented Reality: Principles and Practice,2016
2. Alan B. Craig – Understanding Augmented Reality,2013

Reference book

1. Bimber & Raskar – Spatial Augmented Reality,2005
2. Furht – Handbook of Augmented Reality,2011

ANALYSIS OF SUSTAINABLE ENERGY SYSTEMS

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

SEMESTER – VI

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 fundamentals of sustainable energy and its global relevance.
2. Analyse the performance of various renewable energy systems.
3. Evaluate energy systems based on efficiency, environmental, and economic aspects.
4. Study energy storage and integration of renewable systems.
5. Apply analytical approaches for optimization of sustainable energy systems.

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 Fundamentals of Sustainable Energy Systems	**09 Hours**
Topics: Concept of sustainability, sustainable development, global and Indian energy scenario, classification of energy resources, overview of renewable energy technologies and energy systems. Engineering Applications: Energy planning, resource assessment, and evaluation of sustainable energy policies and systems.	
UNIT – II: Solar and Wind Energy Systems Analysis	**09 Hours**

Topics: Solar thermal and photovoltaic systems, solar radiation analysis, PV system design and performance. Wind energy systems, wind characteristics, turbine types, and power generation analysis. Engineering Applications: Design and performance evaluation of solar PV plants and wind farms, site selection, and energy yield estimation.	
UNIT – III: Biomass, Hydro and Emerging Energy Systems	**09 Hours**
Topics: Biomass energy conversion (biochemical and thermochemical), hydro power systems, geothermal energy, ocean thermal energy, and tidal energy systems. Engineering Applications: Design and analysis of biomass plants, hydroelectric systems, and emerging renewable energy technologies.	
UNIT – IV: Energy Storage and System Integration	**09 Hours**
Topics: Energy storage systems including thermal, mechanical, and electrochemical storage. Hybrid energy systems, grid integration, and smart energy systems. Engineering Applications: Design of hybrid renewable energy systems, energy storage selection, and integration with power grids.	
UNIT – V: Sustainable Energy System Analysis and Optimization	**09 Hours**
Topics: Performance evaluation using efficiency, environmental impact, and economic indicators. Energy economics including cost analysis, payback period, and lifecycle assessment. Engineering Applications: Techno-economic analysis of energy systems, decision-making for sustainable energy projects, and system optimization.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Understand sustainability concepts and energy systems.
2	Analyse solar and wind energy systems.
3	Evaluate biomass, hydro, and emerging energy systems.
4	Analyse energy storage and system integration.
5	Apply system-level analysis and optimization techniques for sustainable energy 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	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	-	-	-		1	2
CO5	1	1	1	2	-	-	2	-	-	-		1	2

Textbooks

1. Vezzoli, C., Kohtala, C., Srinivasan, A., Xin, L., Fusakul, M., Sateesh, D. and Diehl, J.C.,2017.

2. J. Twidell, T. Weir, Renewable Energy Resources, Taylor and Francis, 4th Edition, 2021.
3. Product-service system design for sustainability. Routledge. [this is a copy-left bookavailable online] http://www.lens-india.org,

Reference books

1. G. Boyle (Editor), Renewable Energy: Power for a Sustainable Future, Oxford University press, 3rd Edition, 2012.
2. S. C. Bhattacharyya, Energy Economics Concepts, Issues, Markets and Governance, springer, 2nd Edition, 2019.

Additive Manufacturing & Product Development

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

SEMESTER – VI

Course Code	:		**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 working principles, capabilities, and limitations of major additive manufacturing processes used in industry.
2. Apply design-for-additive-manufacturing (DfAM) concepts to develop optimized, lightweight, and functional mechanical components.
3. Use industry-standard AM software tools for CAD, topology optimization, slicing, and process simulation.
4. Evaluate material selection criteria for polymers, metals, ceramics, and composites in AM contexts.
5. Analyze post-processing, quality control, and inspection techniques relevant to AM-fabricated parts.
6. Apply AM knowledge to industrial product development workflows including prototyping, tooling, and direct part production.

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 Fundamentals of Additive Manufacturing with AI-driven Process Selection	**06 Hours**

This module introduces the complete additive manufacturing (AM) ecosystem, covering process classifications, digital workflows from CAD to final part, and comparison with conventional manufacturing. AI is integrated through intelligent process selection tools that analyse geometry, material, and cost constraints to recommend optimal AM techniques. In industrial contexts, this enables faster decision-making for aerospace components, automotive tooling, and medical implants, where engineers can rapidly evaluate whether technologies like powder bed fusion or material extrusion are most suitable. The module emphasizes how AI accelerates the transition from prototyping to full-scale digital manufacturing within Industry 4.0 environments.

UNIT – II Advanced AM Materials with AI-based Property Prediction	**06 Hours**

This module focuses on polymers, metals, composites, and emerging materials used in AM, along with their microstructural behaviour and process-dependent properties. AI integration is achieved through machine learning models that predict mechanical properties such as strength and porosity based on process parameters. Industrial applications include aerospace-grade titanium components, biomedical implants, and high-performance automotive parts, where AI helps optimise material selection and reduce experimental trials. The module highlights how data-driven material intelligence improves reliability and accelerates innovation in manufacturing industries.

UNIT – III Design for Additive Manufacturing (DfAM) with Generative AI	**06 Hours**

This module covers advanced design methodologies including topology optimisation, lattice structures, and part consolidation tailored for AM. AI plays a central role through generative design and automated rule-checking systems that create optimised geometries based on performance constraints. In industrial applications, this leads to lightweight aerospace brackets, efficient heat exchangers, and customised medical implants. The integration of AI significantly reduces design cycles and enables engineers to explore complex geometries that are not feasible with traditional design approaches.

UNIT – IV Post-Processing, Quality Assurance, and AI-based Inspection	**06 Hours**

This module addresses finishing processes, dimensional accuracy, defect analysis, and quality standards in AM production. AI integration includes computer vision and machine learning techniques for real-time defect detection, predictive distortion analysis, and digital twin-based monitoring. Industrial applications span aerospace turbine components, oil and gas valves, and medical devices, where quality assurance is critical. AI enhances inspection speed and accuracy, enabling automated quality control systems that reduce human error and improve production reliability.

UNIT – V AM in Product Development, Sustainability, and AI-driven Smart Manufacturing	**06 Hours**

This module explores the role of AM across the product lifecycle, including rapid prototyping, direct digital manufacturing, and supply chain transformation. AI is used for cost estimation, lifecycle assessment, and business case generation, helping industries evaluate the economic and environmental feasibility of AM adoption. Industrial applications include mass customisation in consumer goods, on-demand spare parts in defence, and sustainable manufacturing in automotive sectors. The module highlights future trends such as AI-enabled autonomous factories, 4D printing, and digital inventory systems, positioning AM as a core technology in next-generation smart manufacturing.

LAB COMPONENT 30 HRS

[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	Understand the principles and processes of additive manufacturing technologies and their industrial relevance.
2	Select appropriate AM processes and materials for mechanical component design and industrial product development.
3	Apply CAD/CAM and AM software tools for design-to-fabrication workflows in industrial settings.
4	Analyse and evaluate the quality, structural integrity, and post-processing requirements of AM-fabricated parts.
5	Apply AM technologies to industrial product development, including prototyping, tooling, and end-use part production.

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

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: 978-1493921130.

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.

DESIGN OF MACHINE ELEMENTS

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

SEMESTER – V

Course Code	:		**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:

6. Understand the stresses in machine members due to various types of loads and failure of components according to theories of failures.
7. Analyze the components under variable loading for infinite and finite life.
8. Design of machine elements under torsion, bending, axial loads and a combination of these.
9. Design of permanent and temporary joints and fasteners for a given load to be transmitted. Design of various screws, keys, coupling and shafts.
10. To understand use of different types of springs and determine safe design of spring under static and fluctuating loading conditions.
11. To understand the standard nomenclature, forces, failures, application, design procedure of Spur and Helical gears (As per AGMA)
12. 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
13. To understand the design procedure, failures and application of Ball Bearings and Sliding contact bearing
14. 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	**06 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 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.	
UNIT – II	**06 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. 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.	
UNIT – III	**06 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 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	
UNIT – IV	**06 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. 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	
UNIT – V	**06 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. 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.	

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 Courseed 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	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

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.

NOISE, VIBRATION AND HARSHNESS

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

SEMESTER – VI

Course Code	:		**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. 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	**06 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	**6 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	**06 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	**06 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	**06 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 30 HRS	
• Modal Analysis of a Cantilever Beam Using FEA • Extract natural frequencies and mode shapes using finite element software. • Harmonic Response Analysis of a Beam or Plate • Study the steady-state forced vibration response under harmonic loading. • Transient Dynamic Analysis of a Suspension System • Simulate the transient vibration response of a simplified vehicle suspension to road inputs. • 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	
	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

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

OPEN ELECTIVES-1

MATERIALS FOR ENGINEERING APPLICATIONS

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

SEMESTER – VI

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 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	**09 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	**09 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	**09 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	
	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

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.

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

SEMESTER – VI

Course Code	:		**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	**09 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	09Hours
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	09 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	09 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	
	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.

INDUSTRIAL ROBOTICS

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

SEMESTER – VI

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, 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	**09 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	**9 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	09 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	09 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	09 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	
	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

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.

PROFESSIONAL ELECTIVE II

Drives & Control systems

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

SEMESTER – VI

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 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	**09 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	**09 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	**09 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

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.

MATERIALS FOR ADDITIVE MANUFACTURING
[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VI

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 material selection and advanced materials used in additive manufacturing, including composites, biomaterials, and smart materials.
2. Understand additive manufacturing systems, design principles, and product development aspects including topology optimization and build orientation.
3. Apply mathematical modeling and simulation techniques for analyzing AM processes, defects, and process parameters.
4. Explore applications of additive manufacturing in biomedical, aerospace, automotive, and customized product domains.
5. Understand rapid manufacturing techniques and advancements in hybrid and smart manufacturing technologies.

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**
Selection of materials for manufacturing with focus on multiple material systems used in additive manufacturing. Study of metal AM materials, composites, biomaterials, ceramics, bio-ceramics, and hierarchical materials inspired by biomimetics. Introduction to shape-memory materials, 4D printing, and bio-active materials. Discussion on multifunctional and functionally graded materials in AM. CoE LAB: material characterization and AM material demonstration.	

UNIT – II: Design and Systems in Additive Manufacturing	**09 Hours**
Overview of machines used in additive manufacturing and secondary rapid prototyping processes. Concepts of intellectual property, product development, and commercialization in AM. Study of current trends and future directions. Design for AM including build orientation,	

topology optimization, and conformal cooling channels. CoE LAB: design optimization and AM system exposure.

UNIT – III: Mathematical Models in Additive Manufacturing	09 Hours
Selection of AM processes using decision-making methods and process planning. Modeling and analysis of defects, residual stresses, and thermal behavior. Case studies on powder bed fusion and droplet-based printing processes. Evaluation of fabrication time, cost, and optimal orientation. Study of transport phenomena, thermal cycles, and bead formation in cladding processes. CoE LAB: simulation of AM processes and defect analysis.	
UNIT – IV: ADDITIVE MANUFACTURING FOR BIO MEDICAL DEVICES & OTHERS	**09 Hours**
Applications of AM in bio-microfluidics, tissue engineering, and medical device fabrication. Use of CAD-based approaches and clinical-grade materials in biomedical applications. Study of direct digital manufacturing, distributed manufacturing, and mass customization. Applications across aerospace, automotive, architecture, consumer products, and personalized healthcare. CoE LAB: biomedical modeling and application-based demonstrations.	
UNIT – V: RAPID MANUFACTURING OBJECTS	**09 Hours**
Rapid manufacturing of polymeric, metallic, and ceramic components through direct and indirect methods. Advancements in hybrid manufacturing processes and integration of multiple technologies. Introduction to smart materials and their role in next-generation manufacturing. CoE LAB: rapid prototyping and hybrid manufacturing demonstrations.	

Course Outcome	Description
1	Explain material characteristics and selection criteria for additive manufacturing, including advanced and multifunctional materials.
2	Apply design principles and system knowledge for efficient additive manufacturing and product development.
3	Analyze additive manufacturing processes using mathematical models to evaluate defects, cost, and performance.
4	Evaluate the use of additive manufacturing in biomedical and industrial applications.
5	Analyze rapid manufacturing methods and advancements in hybrid processes 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

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.

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

SEMESTER – VI

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 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	**09Hours**
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	**09 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	09 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:	**09 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:	**09 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

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.

DYNAMICS & CONTROL OF MECHANICAL SYSTEMS

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

SEMESTER – VI

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 fundamentals of dynamics and vibration in mechanical systems.
2. Develop mathematical models of mechanical systems using differential equations.
3. Analyse system response in time and frequency domains.
4. Understand principles of feedback control systems and stability analysis.
5. Apply modern tools and AI-based techniques for system modelling and control 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 : Dynamic System Modeling	**09 Hours**

Introduction to dynamic systems, Newton's second law, D'Alembert's principle, energy methods, lumped parameter modeling, mechanical system elements (mass, spring, damper), electrical-mechanical analogies.
Automotive suspension systems, robotic arms, vibration isolators. AI-assisted system modeling and parameter estimation from experimental data

UNIT – II: Vibration Analysis	**09 Hours**

Free vibration of single degree of freedom (SDOF) systems, damping, logarithmic decrement, forced vibration, resonance, transmissibility, vibration isolation
Machine vibration control, building structures, rotating machinery. AI-based vibration signal analysis and fault detection.

UNIT – III: Multi-Degree and Continuous Systems	**09 Hours**
Multi-degree-of-freedom (MDOF) systems, natural frequencies and mode shapes, orthogonality, continuous systems (beam vibration basics). Structural dynamics, aerospace structures, machine tool design. Machine learning models for modal analysis and structural health monitoring.	
UNIT – IV: Control System Fundamentals	**09 Hours**
Introduction to control systems, open-loop and closed-loop systems, transfer functions, block diagrams, signal flow graphs, state-space representation. Industrial automation, servo systems, process control. AI-assisted system identification and control parameter tuning.	
UNIT – V: Stability and Control Design	**09 Hours**
Time response analysis, stability (Routh-Hurwitz criterion), root locus, frequency response (Bode plots, Nyquist criterion), PID controllers. Robotics control, automotive cruise control, aerospace guidance systems. **AI**-based controller tuning (auto PID tuning), predictive control strategies.	

Course Outcome	Description
1	Model mechanical systems using differential equations and state-space representation.
2	Analyse free and forced vibrations of mechanical systems.
3	Evaluate system response using time-domain and frequency-domain methods.
4	Apply control system principles to design stable feedback systems.
5	Use computational and AI tools to simulate and optimize dynamic 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	2	2	3	-	-	-	-	-	-	-	-	-	1
CO3	2	2	3	-	-	-	-	-	-	-	-	-	1
CO4	1	1	3	-	-	-	-	-	-	-	-	-	1
CO5	2	2	3	-	-	-	-	-	-	-	-	-	1

Textbooks

3. Rao, S. S., *Mechanical Vibrations*, Pearson
4. Ogata, K., *Modern Control Engineering*, Prentice Hall.

Reference book

3. Kuo, B. C., *Automatic Control Systems*, Wiley
4. Inman, D. J., *Engineering Vibration*, Pearson.

MICRO ELECTRO MECHANICAL SYSTEMS (MEMS)

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

SEMESTER – VI

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. Introduce fundamental concepts, design principles, and industrial relevance of Micro-Electro-Mechanical Systems (MEMS).
2. Develop understanding of materials, substrates, and smart materials used in MEMS fabrication.
3. Provide knowledge of microfabrication techniques including lithography, deposition, and micromachining processes.
4. Familiarize students with working principles and applications of MEMS-based sensors and microactuators.
5. Expose students to AI-enabled modeling, simulation, and emerging applications of MEMS 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	**09 Hours**

Introduction to Micro-Electro-Mechanical Systems (MEMS), covering definition, historical development, and fundamental concepts. Overview of microfluidics, microelectronics, and microsystems with focus on design, fabrication, working principles, and applications. Integrated circuit fabrication processes are discussed along with the growing industrial potential of MEMS technologies. Indicates NVIDIA-DLI Certification Course integration in microsystem modeling and AI-based design insights.

UNIT – II: Substrates and Wafers	**09 Hours**
Study of materials used in MEMS, including substrates and wafers with emphasis on silicon and its properties, compounds, and piezoresistive behavior. Alternative materials such as gallium arsenide, quartz, polymers, and conductive polymers are explored. Introduction to smart materials like shape memory alloys and their role in MEMS applications. Indicates NVIDIA-DLI Certification Course integration in material modeling and simulation using AI tools.	
UNIT – III: Fabrication Processes	**09 Hours**
Detailed study of MEMS fabrication techniques including photolithography, photoresist applications, and advanced lithography methods such as X-ray, electron beam, and nanolithography. Processes like ion implantation, diffusion, thin film deposition, chemical and physical vapor deposition are covered. Bulk and surface micromachining, LIGA, laser ablation, and micro-stereolithography for 3D microfabrication are also discussed. Indicates NVIDIA-DLI Certification Course integration in computational fabrication modeling and digital twin approaches.	
UNIT – IV: Sensors	**09 Hours**
Fundamentals of microsensors including classification and working principles of physical, thermal, electrical, and mechanical sensors. Study of integrated, intelligent, and smart sensors along with chemical and biosensors used in modern applications. Emphasis is placed on sensing mechanisms and real-world MEMS-based sensor systems. Indicates NVIDIA-DLI Certification Course integration in AI-enabled sensing and data interpretation.	
UNIT – V: Micro actuators	**09 Hours**
Principles of microactuation including electromagnetic, thermal, and mechanical actuation techniques. Design and working of microactuators such as microvalves, micropumps, and micromotors are explored. Applications in systems like inkjet printers and micromirror projection devices are discussed. Introduction to micro-opto-electromechanical systems (MOEMS) and devices such as MOSFET-based systems, highlighting multidisciplinary applications. Indicates NVIDIA-DLI Certification Course integration in intelligent actuation and control systems.	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Explain the fundamentals, components, and applications of MEMS in engineering systems.
2	Analyze material properties and select suitable substrates for MEMS design and fabrication.
3	Apply microfabrication techniques such as lithography, deposition, and micromachining in MEMS development.
4	Evaluate the performance of MEMS sensors and microactuators for various engineering applications.
5	Assess modern MEMS applications integrating AI, smart systems, and multidisciplinary technologies.

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.

DLI Course Mapped
Fundamentals of Accelerated Computing with Modern CUDA C++
DLI Learning Path
https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-AC-01+V2

Entrepreneurial Finance & AI-Driven Deep-Tech Start-ups
[As per Choice Based Credit System (CBCS) scheme]

SEMESTER – VII

Subject Code	:		**Credits**	:	03
Hours / Week	:	03 Hours	**Total Hours**	:	45 Hrs
L–T–P-J	:	3–0–0-0			

Prerequisites: - Basics of Economics, AI/ML Fundamentals, Data Science

Course Learning Objectives:
This Course will enable students to:
1. Understand fundamentals of entrepreneurial finance and start-up ecosystems.
2. Analyse valuation methods and funding strategies for AI-driven start-ups.
3. Apply AI tools for financial modelling, forecasting, and market analysis.
4. Develop skills to design, pitch, and scale deep-tech ventures.
5. Evaluate ethical, regulatory, and societal implications of AI entrepreneurship.

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	**09 Hours**

Foundations of Entrepreneurial Finance

Start-up ecosystem overview, types of start-ups (SaaS, AI, Deep-Tech), financial statements (Profit & Loss, Balance Sheet, Cash Flow), unit economics (Customer Acquisition Cost, Lifetime Value), break-even analysis.

UNIT – II	**09 Hours**

Start-up Valuation & Funding Strategies

Start-up valuation methods (DCF, Comparable, Scorecard), capitalization tables, equity vs debt financing, funding stages (Seed, Series A/B/C), venture capital, angel investors, government funding schemes.

UNIT – III	**09 Hours**

AI-Driven Business Models & Deep-Tech Ventures AI business models (platform, API-based, subscription), deep-tech domains (AI, robotics, IoT, quantum computing), product-market fit, competitive analysis, monetization strategies	
UNIT – IV	**09 Hours**
Financial Planning, Forecasting & Scaling Financial projections, burn rate, runway, scenario planning, scaling strategies, growth metrics, exit strategies (IPO, M&A).	
UNIT – V	**09 Hours**
Legal, Ethical & Future of AI Entrepreneurship Start-up legal frameworks, intellectual property (patents, copyrights), AI regulations, data privacy laws, ESG principles, future trends in AI entrepreneurship	

Course Outcome	Description	Bloom's Taxonomy Level
At the end of the course the student will be able to:		
CO1	Apply financial concepts such as cash flow and valuation	L3
CO2	Design AI-driven business models for deep-tech ventures	L3
CO3	Analyze startup funding strategies	L4
CO4	Develop financial projections and pitch decks	L6
CO5	Build scalable and ethical AI startups	L3

Table: Mapping Levels of COs to POs / PSOs

COs	Program Outcomes (POs)											Program Specific Outcomes (PSOs)	
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO 1	PSO 2
CO1	3	2	2	2	2				3	3	3	3	2
CO2	3	3	2	2	3	2			3	3	3	3	2
CO3	3	3	2	3	3	2			3	3	3	3	2
CO4	2	3	2	3	3	2			3	3	3	3	2
CO5	2	3	2	3	3	2			3	3	3	3	2

TEXT BOOKS

1. Brad Feld & Jason Mendelson – *Venture Deals*

2. Eric Ries – *The Lean Start-up*

REFERENCE BOOKS

1. Ash Maurya – *Running Lean*
2. Scott Kupor – *Secrets of Sand Hill Road*
3. Harvard Business Review – Entrepreneurship Articles
4. NASSCOM & Start-up India Reports

ROBOTICS & AUTONOMOUS SYSTEMS

[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. Understand the fundamentals of robotics, robot classification, robot anatomy, end effectors, workspaces, and industrial applications.
2. Apply coordinate transformations, homogeneous transformation matrices, Denavit-Hartenberg representation, forward kinematics, inverse kinematics, Jacobian concepts, and trajectory planning.
3. Analyse robot actuators, sensors, dynamics, feedback control, and safety requirements for robotic systems.
4. Explain mobile robot platforms, perception, localization, mapping, path planning, obstacle avoidance, and autonomous navigation.
5. Use AI-assisted tools and simulation environments to design, validate, debug, and ethically evaluate robotic and autonomous system solutions.

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 Fundamentals of Robotics and Robot Architecture	06 Hours

Introduction to robotics: history, growth, laws and ethics of robotics, robot definition, robot anatomy, links, joints, degrees of freedom, end effectors, grippers, robot configurations: Cartesian, cylindrical, spherical, SCARA, articulated and parallel robots. Industrial robots, collaborative robots, service robots, autonomous robots, AGVs/AMRs, drones, and robotic cells. Robot specifications: payload, reach, accuracy, repeatability, resolution, speed, work envelope, compliance, and safety categories. Basic robot programming methods: teach pendant, offline programming, and simulation-based programming.

UNIT – II: Robot Kinematics and Trajectory Planning	**06 Hours**
Position and orientation representation, coordinate frames, rotation matrices, Euler angles, homogeneous transformation matrices, compounding transformations, Denavit-Hartenberg parameters, forward kinematics of serial manipulators, introduction to inverse kinematics, multiple solutions and singularities. Jacobian matrix, velocity kinematics, workspace, manipulability, statics basics, joint-space and Cartesian-space trajectory planning, polynomial trajectories, point-to-point motion, continuous-path motion, and interpolation concepts.	
UNIT – III: Robot Dynamics, Actuators, Sensors and Control	**06 Hours**
Forces and torques in robotic systems, basic dynamic modelling concepts, inertia, Coriolis and gravity effects, Lagrange/Newton-Euler overview, actuator types: DC motors, servo motors, stepper motors, BLDC motors, pneumatic and hydraulic actuators, transmissions, gears, belts, lead screws and harmonic drives. Sensors: encoders, potentiometers, IMU, force/torque sensors, proximity sensors, tactile sensors, LiDAR, ultrasonic sensors, cameras, and machine vision. Feedback control, PID control, joint control, position/velocity/force control, stability, calibration, error sources, safety interlocks, emergency stop, and risk assessment.	
UNIT – IV: Mobile Robotics and Autonomous Navigation	**06 Hours**
Autonomous systems overview, mobile robot classifications, wheeled robot kinematics, differential drive, skid steering, Ackermann steering basics, odometry, dead reckoning, sensor fusion, localization, mapping, SLAM concepts, occupancy grids, path planning algorithms: graph search, Dijkstra, A*, potential field, sampling-based planning overview, trajectory tracking, obstacle detection, collision avoidance, navigation stack architecture, mission planning, and simulation of autonomous robots.	
UNIT – V: AI-Enabled Robotics, Human-Robot Interaction and System Integration	**06 Hours**
AI in robotics: perception, decision-making, learning from data, supervised learning, reinforcement learning overview, imitation learning overview, computer vision, object detection, grasp planning, behaviour trees, task planning, cloud/edge robotics, digital twin of robotic systems, virtual commissioning, ROS/ROS 2 concepts, simulation environments, human-robot interaction, collaborative robotics, safety standards overview, cybersecurity, reliability, maintainability, sustainability, and ethical issues in autonomous systems.	

LIST OF LABORATORY/PRACTICAL EXPERIMENTS ACTIVITIES TO BE CONDUCTED (IF ANY) TOTAL 30 HRS
1. Study of robotic components: links, joints, end effectors, actuators, sensors, controller, teach pendant, and safety devices. 2. Simulation of a 2R/3R planar robotic manipulator and verification of forward kinematics. 3. Preparation of Denavit-Hartenberg table and end-effector position calculation for a serial robot arm. 4. Inverse kinematics and workspace visualization for a simple robotic manipulator. 5. Trajectory planning for pick-and-place motion using MATLAB/Python/robot simulation software. 6. PID control simulation for a DC motor or robotic joint position control system. 7. Sensor integration exercise using proximity/ultrasonic/encoder/IMU data for basic robot decision-making. 8. Mobile robot differential-drive modelling and odometry simulation. 9. Path planning and obstacle avoidance simulation using grid-based maps. 10. Basic ROS/ROS 2 or simulator-based autonomous navigation demonstration using TurtleBot/Webots/Gazebo/CoppeliaSim or equivalent tools.

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain the fundamentals of robotic systems, robot configurations, mechanical structure, end effectors, sensors, actuators, and applications in mechanical engineering industries.
2	Apply transformation matrices, Denavit-Hartenberg parameters, forward and inverse kinematics, Jacobian concepts, and trajectory planning for serial manipulators.
3	Analyse robot dynamics, actuator selection, sensing systems, and feedback control strategies for safe and accurate robotic operation.
4	Develop basic autonomous mobile robot models involving perception, localization, mapping, path planning, obstacle avoidance, and navigation logic.
5	Evaluate robotic and autonomous systems using simulation, AI-assisted analysis, safety, reliability, sustainability, human-machine interaction, and responsible AI principles.

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

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

Textbooks

- Craig, J. J., Introduction to Robotics: Mechanics and Control, Pearson.
- Siciliano, B., Sciavicco, L., Villani, L., and Oriolo, G., Robotics: Modelling, Planning and Control, Springer.
- Spong, M. W., Hutchinson, S., and Vidyasagar, M., Robot Modeling and Control, Wiley.
- Corke, P., Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer.

Reference Books

- Niku, S. B., Introduction to Robotics: Analysis, Control, Applications, Wiley.
- Groover, M. P., Automation, Production Systems, and Computer-Integrated Manufacturing, Pearson.

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)	**09 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	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

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.

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.

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.	
UNIT – III: Quality Management Systems	**09 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	
UNIT – IV: Reliability	**09 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	**09 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.	

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	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

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

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	09 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).	

UNIT – II: Solar Energy	09 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.	
UNIT – III:Wind Energy	**09 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).	
UNIT – IV: Energy from Biomass	**09 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.	
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	

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	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. 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

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	**09 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	**09 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	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. 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.

Professional Elective-III

Robot Kinematics and Dynamics

[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 a strong understanding of robotic system fundamentals, including coordinate transformations, kinematics, and basic dynamic principles.
2. Analyze and solve forward and inverse kinematics problems for various robotic manipulators.
3. Evaluate differential motions, velocity relationships, and trajectory planning in robotic systems.
4. Apply dynamic modeling techniques, including force, torque, and energy analysis using Newton–Euler and Lagrangian approaches.
5. Understand advanced concepts such as multi-body dynamics, nonlinear behavior, and the use of computational tools for simulation and modern robotic 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 : Introduction to Robotic Systems	**09 Hours**

Overview of robotics including types of robots and their applications in industrial and service domains. Study of coordinate systems, frame representations, homogeneous coordinates, and transformation matrices used in robotic analysis. A brief review of kinematics and dynamics focusing on concepts relevant to robotic manipulators. CoE: simulation of coordinate

transformations and basic robot modeling.	
UNIT – II: Forward and Inverse Kinematics of Robots	**09 Hours**
Derivation of forward kinematics to determine position and orientation of robotic manipulators. Inverse kinematics techniques for solving end-effector position and orientation. Workspace analysis including reachable and dexterous workspace. Introduction to Jacobian matrix for velocity, force analysis, and identification of singularities. CoE: kinematic modeling and workspace visualization using software tools.	
UNIT – III: Differential Motions and Velocities	**09 Hours**
Study of differential relationships between joint space and Cartesian space. Planning of motion trajectories in joint and task space for smooth robot operation. Velocity kinematics analysis to understand motion characteristics under different configurations. CoE: trajectory planning and velocity simulation exercises.	
UNIT – IV: Robot Dynamics	**09 Hours**
Dynamic modeling of robotic systems using Newton–Euler and Lagrangian approaches. Computation of forces and torques under static and dynamic conditions. Application of energy-based methods for analysis of robotic motion and efficiency. CoE: dynamic simulation and torque analysis of robotic manipulators.	
UNIT – V: Advanced Topics in Robot Kinematics and Dynamics	**09 Hours**
Analysis of multi-body robotic systems and introduction to nonlinear dynamics. Use of computational tools for simulation and modeling of robotic systems. Overview of recent trends such as AI integration and advanced robotic control. CoE: advanced simulation tools and exposure to current research practices.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain the fundamentals of robotic systems, including coordinate frames, transformations, and basic kinematics and dynamics.
2	Solve forward and inverse kinematics problems for robotic manipulators and analyze their workspace.
3	Analyze differential motion, velocity relationships, and plan trajectories in joint and Cartesian space.
4	Apply dynamic modeling techniques to compute forces, torques, and energy in robotic systems.
5	Evaluate advanced robotic concepts such as multi-body dynamics, nonlinear behavior, and simulation-based 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	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

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.

PROCESSING OF PLASTICS AND COMPOSITES

[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 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	**09 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	**09 Hours**

Injection molding, Extrusion, Blow molding, Thermoforming, Rotational molding, Process parameters and their effects on product quality	
UNIT – III: Processing Techniques for Composites	**09 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	**09 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

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.

SOFTWARE DEFINED VEHICLES

[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 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	**09 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	**09 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	**09 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	**09 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	**09 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

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.

Computational Mechanics

[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. Formulate numerical models using discretization of governing equations.
2. Apply finite difference and finite volume methods to engineering problems.
3. Apply fundamental finite element concepts for structural analysis.
4. Analyze convergence, stability, and error in numerical computations.
5. Develop computational workflows and validate results using AI-assisted 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 : Numerical Modelling Basics	**09 Hours**

Topics: Governing equations, discretization, approximation, Finite difference discretization of 1D governing equations, Numerical formulation of bar/heat equation, boundary conditions, simple worked numerical examples, and basic numerical workflow.

Heat conduction, bar problems, and simple field analysis. AI-assisted explanation of discretization and checking of formulation steps.

UNIT – II: Finite Difference and Finite Volume Ideas	**09 Hours**

Grid generation, finite difference approximations, control volume idea, interpolation, and basic discretization error.

Heat transfer and simple transport problems. AI-supported code outline generation, approximation comparison, and error spotting.

UNIT – III: Finite Element and Weak Form Overview	**09 Hours**

Weak form, interpolation, shape functions, element stiffness matrix formulation, elemental assembly, and relation between FE and other numerical methods. Bars, beams, plates, and simple structural systems. AI-based derivation help, matrix check, and model consistency verification	
UNIT – IV : Iterative Solvers, Convergence, and Error	**09 Hours**
Direct and iterative methods, convergence concept, residual, tolerance, condition number, and stability basics. Large numerical systems and repeated analysis tasks. AI-assisted troubleshooting of convergence problems and comparison of solver behaviour.	
UNIT – V: Simple Coding and Verification Workflow	**09 Hours**
Pseudocode, modular programming, verification and validation, result interpretation, and introduction to coupled problems. Basic simulation scripts and engineering post-processing. AI code-generation support, debugging, and result interpretation with human oversight.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply discretization techniques to convert governing equations into solvable numerical models.
2	Apply finite difference and finite volume methods to solve simple engineering problems.
3	Apply basic finite element concepts including weak form, interpolation, and element assembly.
4	Analyze convergence, stability, and error in numerical solutions using appropriate solvers.
5	Develop and verify simple computational workflows, including AI-assisted validation of results.

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	-	-	-

Textbooks:

1. Chapra & Canale — *Numerical Methods for Engineers* (7th Ed., 2015, McGraw-Hill)
2. Logan — *A First Course in the Finite Element Method* (6th Ed., 2016, Cengage)
3. Belytschko et al. — *Nonlinear Finite Elements for Continua and Structures* (2nd Ed., 2013, Wiley)

Reference Books:

1. Zienkiewicz et al. — *The Finite Element Method* (7th Ed., 2013, Elsevier)
2. Ferziger & Perić — *Computational Methods for Fluid Dynamics* (3rd Ed., 2002, Springer)
3. Hughes — *The Finite Element Method* (2000, Dover)
4. Sastry — *Introductory Methods of Numerical Analysis* (5th Ed., 2012, PHI)

Additional Sources

1. NPTEL Online Courses – Numerical Methods and FEM
2. Open educational resources on computational mechanics

DLI Course Mapped

Accelerating Computer-Aided Engineering (CAE) with NVIDIA AI Physics Technology

DLI Learning Path

https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-48+V1

Predictive maintenance & Industrial AI

[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 to:

1. Understand the evolution from reactive and preventive maintenance to AI-driven proactive strategies.
2. Master the acquisition of high-fidelity sensor data and the application of signal pre-processing techniques for feature engineering.
3. Implement supervised and unsupervised machine learning models to detect anomalies and predict Remaining Useful Life (RUL).
4. Develop Digital Twin architectures and Edge AI workflows for real-time industrial monitoring.
5. Critically evaluate the ethical, legal, and security implications of deploying AI in critical infrastructure.

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 : Foundations of Industrial AI & Maintenance Paradigms	09 Hours
Evolution of maintenance (Reactive vs. Preventive vs. Predictive), ROI of PdM, types of Industrial AI (Supervised, Unsupervised, Reinforcement Learning). Gearbox monitoring in wind turbines, robotic arm wear indicators in automotive plants, and jet engine acoustic analysis. Selecting appropriate ML types for specific mechanical failure modes	

UNIT – II: Sensor Data Fusion & Signal Feature Engineering	09 Hours
Industrial IoT (IIoT) sensors, sampling and quantization, time-domain features (RMS, Kurtosis), and frequency-domain analysis (FFT, STFT, Wavelets). Monitoring vibration signatures in high-speed spindles and thermal profiles in power generation turbines. Automated noise cancellation and signal denoising using adaptive filters.	

UNIT – III: Machine Learning for Predictive Modelling	09 Hours
Classification and Regression models, XGBoost, Random Forests, Anomaly Detection (Isolation Forests, PCA), and Health Index modelling. Predicting brake pad wear patterns in fleet logistics and identifying pressure spikes in hydraulic systems. Real-time anomaly flagging against learned operational baselines.	

UNIT – IV: Deep Learning & Advanced Diagnostics	09 Hours
Neural Network basics (MLP), Convolutional Neural Networks (CNN) for visual inspection, LSTMs for time-series, and GANs for synthetic data generation Visual defect detection in production lines and predicting the RUL of aircraft engine bearings. Sequence-to-sequence modelling for forecasting future machine states.	

UNIT – V: Digital Twins, Edge AI & Enterprise Deployment	09 Hours
Digital Twin architecture, Edge computing with Tensor Flow Lite, Model deployment (Docker/APIs), and Ethics/Governance (PII protection, security). Virtual replicas of offshore oil rigs for remote monitoring and edge-deployed vibration alerts on CNC machines. Low-latency inference at the device level to trigger immediate e-stops.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Design and deploy an end-to-end Predictive Maintenance (PdM) pipeline for rotating machinery
2	Calculate the health index of industrial assets using advanced time-frequency domain analysis
3	Construct and train Deep Learning models (LSTMs, CNNs, Auto encoders) for complex fault pattern recognition
4	Optimize maintenance schedules by integrating AI forecasts with managerial decision frameworks and ROI analysis
5	Demonstrate authentic intelligence by validating AI outputs against physics-based engineering principles and domain constraints

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

Textbooks

5. Machine Learning (Alpaydin), Hands-On Machine Learning (Géron)

Reference book

5. Digital Signal Processing (Mitra), Vibration-based Condition Monitoring

Additional Sources

1. NVIDIA Deep Learning Institute (DLI) Workshop materials, Data bricks Academy documentation
2. Data Analytics and Artificial Intelligence for Predictive Maintenance in Industry 4.0
3. Predictive Maintenance in Smart Factories

DLI Course Mapped
Applications of AI for Predictive Maintenance
DLI Learning Path
https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-MF-02+V1

Fixed Equipment's in Oil & Gas 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 provide an understanding of the oil and gas industry, including upstream and downstream operations, static equipment, process systems, and applicable industrial standards.
2. To develop knowledge of design principles and engineering codes for pressure vessels, heat exchangers, columns, piping systems, and related process equipment based on ASME and API standards.
3. To enable students to analyze pressure loads, stress conditions, and structural requirements for safe and reliable operation of process equipment and piping networks.
4. To introduce process safety concepts and equipment integrity management, including over-pressure protection, safety relief systems, inspection practices, and corrosion mechanisms.
5. To build competency in material selection, fabrication methods, welding practices, testing procedures, and maintenance approaches for improving industrial equipment performance and operational reliability.

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 : Introduction to Oil & Gas Equipment and Design Codes	**09 Hours**
Overview of oil and gas industry sectors including upstream and downstream operations. Introduction to static process equipment such as pressure vessels, columns, and heat exchangers and their industrial functions. Design basis and selection of engineering codes based on pressure, temperature, operating conditions, application, and service requirements. Introduction to ASME Section VIII Division 1 & 2, ASME B31.3, API 660, and TEMA standards and their role in equipment design and compliance. **Tool Awareness:** SAP S/4HANA (Plant Maintenance Module) **Basic Need:** To plan, track, and optimize equipment maintenance activities and plant availability. **Utilization:** Used for preventive maintenance, work order management, inspection scheduling, and asset records.	
UNIT – II: Pressure Vessel and Heat Exchanger Design	**09 Hours**
Internal pressure design equations and pressure calculations based on UG-27 provisions. External pressure and vacuum design considerations for equipment stability. Openings and nozzle reinforcement calculations, support systems including skirt and saddle design, and mandatory code appendices for alternative design approaches. Design requirements and code provisions for pressure-containing equipment. **Tool Awareness:** PV Elite – Pressure Vessel and Heat Exchanger Design and Analysis **Basic Need:** To perform safe and code-compliant design and mechanical evaluation of static equipment. **Utilization:** Used for vessel modeling, thickness calculations, nozzle analysis, and design report generation.	
UNIT – III: Stress Analysis and Piping System Design	**09 Hours**
Relevant sections of ASME and related codes covering internal pressure, external pressure, load combinations, allowable stress limits, and design temperature effects. Concept of treating piping systems as beam structures for span calculations and structural thickness determination. Requirements for flexibility analysis and stress analysis in piping systems according to ASME B31.3. **Tool Awareness:** CAESAR II – Piping Stress and Flexibility Analysis **Basic Need:** To evaluate piping integrity under pressure, temperature, and operational loads. **Utilization:** Used for piping stress analysis, support optimization, thermal expansion, and code compliance.	
UNIT – IV: Process Safety and Equipment Protection	**09 Hours**
Principles of over-pressure protection and safety management in process industries. Selection criteria for safety relief devices according to ASME and API standards. Inspection, calibration, testing, and maintenance practices for safety valves. Overview of industrial damage mechanisms including corrosion under insulation (CUI), wet H_2S corrosion, and amine corrosion based on API 571 recommendations. **Tool Awareness:** Reliability Analysis Software (ReliaSoft / Weibull Analysis Tools) **Basic Need:** To improve equipment reliability and reduce unplanned shutdowns. **Utilization:** Used for failure analysis, reliability estimation, maintenance planning, and lifecycle assessment.	

UNIT – V: Metallurgy, Fabrication and Valve Technology	**09 Hours**
Fundamentals of metallurgy and fabrication techniques used in process industries. Welding methods, weld inspection, evaluation procedures, and testing techniques for quality assurance. Classification of industrial valves, operating principles, applications, and inspection requirements according to API 598 standards. Material selection and fabrication considerations for process equipment and piping components. **Tool Awareness:** Digital Inspection and Asset Management Platforms + Primavera P6 for Maintenance Planning and Shutdown Scheduling **Basic Need:** To manage asset health, inspections, maintenance planning, and shutdown activities efficiently. **Utilization:** Used for inspection tracking, asset integrity management, maintenance scheduling, and shutdown execution.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain the fundamentals of the oil and gas industry, including upstream and downstream operations, process equipment, and applicable industrial standards.
2	Apply engineering design principles and international codes for the design and evaluation of pressure vessels, heat exchangers, columns, and piping systems.
3	Analyze internal and external pressure conditions, stress behavior, load combinations, and structural requirements of process equipment.
4	Evaluate process safety measures, over-pressure protection systems, inspection practices, and common industrial damage mechanisms for safe plant operation.
5	Select appropriate materials, fabrication techniques, welding methods, testing procedures, and maintenance practices for reliable industrial equipment performance.

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

Textbooks

1. Dennis R. Moss and Michael Basic, *Pressure Vessel Design Manual*, 4th Edition, Elsevier, 2013.
2. Maan H. Jawad and James R. Farr, *Guidebook for the Design of ASME Section VIII Pressure Vessels*, 3rd Edition, ASME Press, 2010.

3. Philip Ellenberger, *Piping and Pipeline Calculations Manual*, 1st Edition, Elsevier, 2014.

Reference Books

1. Eugene F. Megyesy, *Pressure Vessel Handbook*, 14th Edition, Pressure Vessel Publishing Inc., 2011.
2. Mohinder L. Nayyar, *Piping Handbook*, 7th Edition, McGraw-Hill Education, 2000.

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. To develop understanding of industrial automation system architecture, components, and integration challenges in modern industries.
2. To introduce advanced control strategies, including model-based and data-driven approaches, for efficient process control.
3. To provide knowledge of industrial communication protocols and the design of reliable and secure automation networks.
4. To familiarize students with safety standards such as ISO 13849 and IEC 62061, along with risk assessment techniques.
5. To expose students to emerging trends in industrial automation, including AI, Industry 4.0, and sustainable manufacturing practices.

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 are reviewed with emphasis on advanced sensors, actuators, and modern control elements beyond basic coverage. The hierarchical structure of industrial automation systems, including enterprise, control, and field levels, is examined along with their interactions. Integration challenges such as interoperability, system scalability, and coordination within existing industrial setups are discussed. Indicates NVIDIA-DLI Certification Course integration in AI-enabled

automation systems.	
UNIT – II: Advanced Control Strategies in Automation	**09 Hours**
Advanced control methods including Model Predictive Control (MPC), Fuzzy Logic Control, and Adaptive Control are introduced with industrial relevance. The role of real-time operating systems (RTOS) in ensuring reliability and deterministic performance is explored. Data-driven approaches using machine learning and big data are discussed for predictive maintenance and process optimization. Indicates NVIDIA-DLI Certification Course focusing on AI-driven control and GPU computing.	
UNIT – III: Communication Technologies in Industrial Automation	**09 Hours**
Key industrial protocols such as EtherCAT, Modbus, PROFIBUS, and PROFINET are studied in terms of structure and applications. Industrial network design is discussed with focus on reliability, latency, and cybersecurity. Wireless communication technologies, including sensor networks and mobile systems, are explored for flexible industrial monitoring and control. Indicates NVIDIA-DLI Certification Course integration in industrial communication and edge AI.	
UNIT – IV: Safety and Regulatory Standards	**09 Hours**
Safety standards such as ISO 13849 and IEC 62061 are examined with their role in system design and validation. Regulatory requirements related to safety, environment, and quality are discussed. Hazard analysis and risk assessment methods are introduced for safe and reliable automation operation. Indicates NVIDIA-DLI Certification Course alignment with safety-aware AI systems.	
UNIT – V: Case Studies and Emerging Trends	**09 Hours**
Applications such as collaborative robots, augmented reality in maintenance, and AI-based process control are explored. The contribution of automation to energy efficiency and sustainable manufacturing is analyzed. Emerging trends including Industry 4.0, digital twins, and intelligent autonomous systems are discussed. Indicates NVIDIA-DLI Certification Course integration in advanced industrial AI applications.	

Course Outcome	**Description**
At the end of the course the student will be able to:	
1	Analyze the architecture and components of industrial automation systems, including integration challenges in real-world applications.
2	Apply advanced control strategies such as MPC, fuzzy logic, and data-driven methods for industrial process optimization.
3	Evaluate industrial communication protocols and design secure, reliable automation networks.
4	Interpret safety standards such as ISO 13849 and IEC 62061, and perform hazard analysis and risk assessment.
5	Assess emerging trends in industrial automation, including AI-driven systems, collaborative robotics, and sustainable manufacturing 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	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)**

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

NVIDIA Isaac for Accelerated Robotics

DLI Learning Path

https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-OV-05+V1

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			

<u>Course Learning Objectives:</u>

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 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	**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

FUNDAMENTAL OF DRIVES AND DC MACHINE MODELING

[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 fundamental concepts of electric drives
2. provide knowledge of power converters and inverters
3. analyze the mathematical modeling, drives of SRM and induction motors
4. introduce permanent magnet motor characteristics, drives
5. provide knowledge of various charging technologies

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	9 Hours

Electric Drives

Concept of electric drives - Classifications - Types of loads - Four-quadrant drive - Dependence of loadtorque on various factors - Dynamics of motor-load combination - Steady state stability of an electric drive system - Load Equalization - Control and Analysis of DC drives fed through single-phase and three-phase semi-converter - full-converter - phase-controlled configuration - Vector control - Energy efficient drives -

losses in electrical drive systems	
Unit-2	**9 Hours**
Power Converters for EV: Introduction – Performance parameters of DC-DC conversion – Step-up and step-down converters withRL load – Switching mode regulators – Buck converter – Boost converter – Buck-Boost converter – Cuk converter – Limitations of single stage conversion – Comparison of converters – Inverter's introduction – Performance parameters – Principle of operation – Three phase inverters – Voltage control of three phase inverter – Current source inverter.	
Unit-3	**9 Hours**
Induction Motor Drives: Poly-phase Induction Motor- Characteristics, equivalent circuit, phasor diagram, dq-modelling; Scalar control-based induction motor drive; Vector control-based induction motor drive **SRM Motor Drives** Characteristics - Power converters - Control methods - Rotor position sensing - Closed loop control -Sensor-less operation	
Unit-4	**9 Hours**
Permanent Magnet Motor Drives PMBLDC introduction - Working principle - Magnetic circuit analysis - Torque and emf equations - Power converter - Closed loop control – PMSM introduction – Working principle - Torque equation -Phasor diagram – dq modelling - Vector control based PMSM drive **Generation and Transmission of Electrical Energy** Introduction – Types of generating stations - Controlling the power balance between generator and load – Hydropower generation stations – Thermal generating stations - Components of powerdistribution system – Tower grounding – Equivalent circuit of a line - Evolution of Electric Grid - Smart Grid Concept - Difference between conventional and Smart Grid - Phasor Measurement Unit	
Unit-5	**9 Hours**
EV Charging Technology: EV charging technology - Types of charging systems - Schematic comparison between AC Charger andDC Fast charger - Charging standards - Fundamental principle of wireless charging - Wireless charging technologies - Comparison between Conductive and Inductive charging schemes of EV – Wireless charging methods for EVs. **Contemporary issues:** Guest lectures from Industries, Research and Development Organisations	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply the principles of electric drives to analyze and control various types of loads and drive systems, including four-quadrant drives and energy-efficient drives.
2	Implement and evaluate different DC-DC converters and inverters, including buck, boost, buck-boost, and three-phase inverters, to optimize performance parameters for electric vehicle applications.
3	Analyze and design control strategies for poly-phase induction motor drives and switched reluctance motor (SRM) drives, including both scalar and vector control methods.
4	Develop and implement control methods for permanent magnet motor drives, including PMBLDC and PMSM, utilizing magnetic circuit analysis, torque equations, and dq modeling.
5	Evaluate and compare various EV charging technologies, including AC and DC charging systems, wireless charging technologies, and different charging standards, to enhance the efficiency and effectiveness of EV charging infrastructure

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

Textbooks:

1. Wildi, T. (2014). Electrical Machines, Drives, and Power Systems (6th ed.). Pearson India.
2. Mohan, N. (2011). Power Electronics: A First Course. John Wiley & Sons Inc.

Reference Books:

1. Krishnan, R. (2017). Permanent Magnet Synchronous and Brushless DC Motor Drives. CRC Press.
2. Muhammad, R. H., Narendra, K., & Ashish, R. K. (2014). Power Electronics Devices, Circuits and Applications. Pearson Education.
3.

Fracture Mechanics [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 of fracture mechanics and crack propagation.
2. Apply analytical and numerical methods to evaluate fracture parameters.
3. Use computational tools such as ANSYS and MATLAB for fracture analysis.
4. Analyze fatigue behavior and predict failure life of engineering components.
5. Integrate AI techniques for data-driven fracture and fatigue prediction.

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 Fracture Mechanics	**06 Hours**
Modes of fracture (Mode I, II, III), Griffith theory and energy balance, energy release rate, crack resistance (R-curve), stable and unstable crack growth, damage tolerance concept, introduction to computational fracture mechanics. Failure analysis of pressure vessels, bridges, aircraft structures.	
UNIT – II Stress Intensity Factor & Crack Modeling	**08 Hours**
Stress intensity factor (SIF), Westergaard approach, analytical solutions for edge and center cracks, mixed-mode fracture, crack path prediction, introduction to FEM in fracture. Crack analysis in machine components, shafts, and plates.	
UNIT – III Numerical Fracture Mechanics (FEA Based)	**09 Hours**
Finite Element Method in fracture, J-Integral, CTOD, XFEM basics, crack propagation techniques, effect of loading and geometry. Simulation of cracks in automotive and aerospace	

components.	
UNIT – IV Plastic Zone & Crack Tip Behavior	**07 Hours**
Crack tip stress fields, plastic zone estimation, plane stress vs plane strain, CTOD, fracture toughness. Design against fracture in thick and thin structures.	
UNIT – V Fatigue, Failure & AI Applications	**09 Hours**
Fatigue mechanisms, Paris law, life prediction, failure analysis, AI in fracture mechanics including regression models and classification techniques. Fatigue analysis of rotating machinery, aircraft wings, and structural components.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain fracture mechanisms and evaluate crack growth behavior.
2	Apply analytical methods to determine stress intensity factors and energy release rates.
3	Perform computational fracture analysis using ANSYS.
4	Analyse fatigue behavior and predict life using numerical methods.
5	Develop AI-based models for fracture and fatigue prediction.

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/

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	**09 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	**09 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	**09 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	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

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 C/C++

DLI Learning Path

https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-AC-01+V1

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	:	0–0–0–06			

Course Learning Objectives:

This Course will enable students to:

1. Develop the ability to conduct a systematic literature survey and identify research gaps using modern AI-enabled tools.
2. Enable students to formulate clear problem statements and select appropriate research supervisors through academic and technical evaluation.
3. Provide knowledge for designing effective research methodologies using simulation tools, experimental techniques, and AI-based approaches.
4. Familiarize students with the use of Center of Excellence (CoE) lab facilities for implementing and validating engineering solutions.
5. Enhance technical documentation, report writing, and presentation skills using AI-assisted tools and modern visualization techniques

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 and Literature Survey

Students conduct a comprehensive literature survey using journals, patents, and technical reports to identify research gaps and define a clear problem statement. AI tools such as NLP-based summarization, keyword extraction, and citation analysis support efficient review. The CoE lab provides access to advanced digital libraries and AI-driven research platforms for high-quality analysis.

2. Finding the Supervisor

Students select a supervisor based on domain expertise and research alignment. AI-based academic profiling tools assist in identifying suitable faculty. The CoE lab facilitates mentorship, expert interactions, and interdisciplinary discussions to refine project direction.

3. Finalizing Methodology / Design Phase

Students develop the research methodology, including experiments, simulations, or theoretical models. AI techniques such as machine learning, optimization, and digital twins enhance design and analysis. The CoE lab supports implementation using CAD/CAE tools, robotics systems, IoT platforms, and AI frameworks.

4. Report Submission and Presentation

Students prepare a structured report and present their outcomes using AI-supported tools for writing, visualization, and plagiarism checking. The CoE lab enables prototype demonstration, simulations, and industry-oriented presentations for effective communication.

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

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	**09 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	**09 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	**09 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

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

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.

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	09 Hrs
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	09 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	**09 Hours**
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.

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	**9 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	9 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	**9 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	**9 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.

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

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

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.

Design Optimization

[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 fundamentals of optimization and its role in engineering design
2. Formulate real-world design problems as mathematical optimization models
3. Apply classical and numerical optimization techniques
4. Explore modern optimization methods for complex engineering problems
5. Apply optimization concepts to mechanical 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 Introduction to Design Optimization	**09 Hours**
Engineering design process, need for optimization, classification of optimization problems, objective function, design variables and constraints, formulation of optimization problems, feasible and infeasible regions, graphical solutions. Design improvement in machine components, cost reduction, performance enhancement	
UNIT – II Classical Optimization Techniques	**09 Hours**
Single-variable optimization: exhaustive search, interval halving, golden section method. Multivariable optimization: necessary and sufficient conditions, Lagrange multipliers, Optimization of dimensions in machine design problems	
UNIT – III Numerical Optimization Methods	**09 Hours**

Steepest descent method, conjugate gradient method, Newton's method, penalty and barrier methods, basics of linear programming, Optimization of engineering systems with constraints	
UNIT – IV Advanced Optimization Techniques	**09 Hours**
Genetic algorithms, simulated annealing, particle swarm optimization (concepts), multi-objective optimization, Pareto optimality, Design of complex engineering systems and decision-making problems	
UNIT – V Design Optimization Applications	**09 Hours**
Structural optimization (size, shape), optimization of beams, shafts, springs, cost and weight minimization, reliability considerations, introduction to computational tools (MATLAB/ANSYS/Fusion), Real-world design optimization in mechanical systems	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Formulate engineering design problems as optimization problems
2	Apply classical optimization methods for single and multivariable problems
3	Use numerical methods for solving constrained and unconstrained optimization problems
4	Analyse and apply modern optimization techniques in engineering design
5	Solve real-world mechanical design problems using optimization 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	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

Text Books

1. Engineering Optimization: Theory and Practice – Singiresu S. Rao, *Engineering Optimization: Theory and Practice*, Wiley
2. Optimization for Engineering Design: Algorithms and Examples – Kalyanmoy Deb, *Optimization for Engineering Design: Algorithms and Examples*, PHI Learning

Reference Books

1. Numerical Optimization – Jorge Nocedal and Stephen J. Wright, *Numerical Optimization*, Springer

2. Introduction to Optimum Design – Jasbir S. Arora, *Introduction to Optimum Design*, Elsevier
3. Engineering Design Optimization – Raphael T. Haftka and Zafer Gürdal, *Elements of Structural Optimization* (commonly used for design optimization), Springer

Additional Sources

1. NPTEL Online Courses – Optimization Techniques (IIT lectures)
2. MIT OpenCourseWare – Optimization and Design courses

Cyber Physical Systems
[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 to:

1. Understand the architecture, design principles, and real-time operation of Cyber Physical Systems.
2. Study advanced sensing, embedded computing, communication, and IoT integration in CPS.
3. Analyze intelligent automation, industrial CPS, and smart infrastructure systems.
4. Evaluate cybersecurity, safety, reliability, and ethical issues in CPS environments.
5. Explore emerging applications of CPS in Industry 4.0, healthcare, autonomous systems, and sustainable technologies.

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 Fundamentals and Architecture of Cyber Physical Systems	**09 Hours**
Introduction to Cyber Physical Systems, characteristics and evolution of CPS, architecture of CPS, components of CPS, integration of computation and physical systems, embedded systems in CPS, sensors and actuators, feedback systems, real-time systems, CPS design principles, modeling and simulation concepts. Smart devices, industrial automation, intelligent monitoring systems, robotics.	

UNIT – II Embedded Systems, IoT, and Communication in CPS	**09 Hours**
Advanced embedded systems for CPS, microcontrollers and embedded platforms, IoT architecture, wireless sensor networks, machine-to-machine communication, communication protocols, edge computing, cloud computing integration, data acquisition systems, real-time data communication. Smart homes, wearable systems, industrial IoT, environmental	

monitoring, connected devices.	
UNIT – III Intelligent Automation and Industrial CPS	**09 Hours**
Control systems in CPS, intelligent automation, PLC and SCADA systems, robotics and autonomous systems, industrial automation networks, predictive maintenance, machine learning in CPS, smart manufacturing, Industry 4.0 concepts, digital twin technology. Smart factories, autonomous vehicles, robotic systems, industrial monitoring and automation.	
UNIT – IV Cybersecurity, Safety, and Ethics in CPS	**09 Hours**
Cybersecurity in CPS, data privacy, authentication and secure communication, safety-critical systems, fault tolerance, reliability engineering, cyber threats and attacks, secure industrial systems, ethical issues in intelligent systems, human-machine interaction, responsible AI usage in CPS. Secure healthcare systems, industrial safety systems, transportation security, smart infrastructure protection.	
UNIT – V Emerging Applications and Future Trends in CPS	**09 Hours**
Cyber Physical Systems in healthcare, smart cities, smart grids, agriculture, transportation systems, renewable energy integration, autonomous systems, AI-enabled CPS, sustainable CPS design, digital transformation, future trends in CPS research and development. Connected healthcare, intelligent transportation, renewable energy systems, precision agriculture, sustainable urban systems.	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Explain the architecture, components, and operational principles of Cyber Physical Systems.
2	Analyse embedded systems, sensors, IoT, networking, and cloud integration in CPS applications.
3	Apply concepts of intelligent automation, real-time monitoring, and control systems in CPS environments.
4	Evaluate cybersecurity, safety, reliability, and ethical challenges associated with CPS deployment.
5	Design and analyse CPS applications for Industry 4.0, smart cities, healthcare, autonomous systems, and sustainable engineering.

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

Textbooks

1. Raj Rajkumar – Cyber Physical Systems

2. Lee and Seshia – Introduction to Embedded Systems: A Cyber Physical Systems Approach
3. K. J. Astrom and R. Murray – Feedback Systems

Reference Books

1. Edward Ashford Lee – Cyber Physical Systems Design
2. Ian F. Akyildiz – Wireless Sensor Networks
3. Klaus Schwab – The Fourth Industrial Revolution
4. Rajkumar Buyya – Internet of Things and Cloud Computing

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 to:

- 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.
- 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.
- 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.
- 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.
- 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 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 Non-Destructive Examination (NDE) and Inspection Techniques	09 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	09 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	09 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	09 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	09 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

3. API, API Recommended Practice 580: Risk-Based Inspection, American Petroleum Institute, Latest Edition.
4. API, API Recommended Practice 581: Risk-Based Inspection Technology, American Petroleum Institute, Latest Edition.

Capstone Project Phase-2

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

Course Code	:		**Credits**	:	10
Hours / Week	:	20 Hours	**Total Hours**	:	300 Hours
L–T–P–S	:	0–0–0–22			

Course Learning Objectives:

This Course will enable students to:

1. Enable students to execute engineering projects by developing prototypes, conducting experiments, and applying systematic problem-solving approaches.
2. Develop skills in data collection and analysis using modern tools, including AI techniques for accurate interpretation of results.
3. Enhance the ability to validate experimental outcomes by comparing them with theoretical models and existing research.
4. Provide exposure to advanced Center of Excellence (CoE) lab facilities for effective implementation, testing, and optimization of solutions.
5. Build competence in drawing meaningful conclusions and proposing future improvements or research directions based on project outcomes.

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

Students implement the project plan by developing prototypes, conducting experiments, and collecting relevant data. Engineering principles and systematic problem-solving techniques are applied to refine designs and overcome practical challenges. AI integration supports this phase through data acquisition systems, predictive analytics, and real-time monitoring, while the CoE lab provides access to advanced equipment, simulation tools, and prototyping facilities for effective implementation.

2. Result Discussion

Students analyze the collected data to extract meaningful insights and validate project objectives. AI-based data analysis tools, including machine learning algorithms and visualization techniques, are used to improve accuracy and interpretation. Results are compared with theoretical models and existing studies to evaluate performance and reliability. The CoE lab environment supports high-end computational tools and benchmarking facilities for detailed analysis.

3. Conclusion

Students summarize the key findings of the project and highlight their significance in the respective field. AI tools assist in identifying patterns, trends, and optimization opportunities. Based on outcomes, students provide recommendations for future research, design improvements, or industrial applications. The CoE lab facilitates validation of results and encourages innovation-driven conclusions aligned with real-world requirements.

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

Research Internship/ Industry Internship

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

SEMESTER – VIII

Course Code	:		**Credits**	:	03
Hours / week	:	03 Hours	**Total Hours**	:	78 Hours
L–T–P–S	:	03–0–0–0			

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	Apply theoretical engineering knowledge to practical problems through supervised research or industry-based projects.
2	Develop technical, analytical, and problem-solving skills through experiential learning and real-world project execution.
3	Demonstrate professional skills through interaction with industry experts, mentors, and multidisciplinary teams.
4	Analyze and document project outcomes using appropriate engineering tools, methods, and technical communication practices.
5	Demonstrate professional competence, ethical practices, and industry readiness through project presentation, report, and supervisor evaluation.

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

Leadership, Policy & Authentic Intelligence

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

SEMESTER – VIII

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

Course Learning Objectives:

This Course will enable students to:

- Understand the fundamentals of engineering and society leadership
- Apply tools of AI ethics, policy
- Develop governance frameworks
- Analyze ethical, societal, and reliability issues in AI 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.
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- 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 Foundations + Leadership	**09 hours**

What is authentic intelligence? Beyond artificial intelligence

Engineering in society: roles, responsibilities, and power Systems thinking for engineers — feedback loops and stakeholder mapping

History of technology governance and the leadership–policy–AI nexus

Leadership models: transformational, servant, and distributed

Decision-making under uncertainty and high-stakes environments

Managing diverse, interdisciplinary teams

Communicating technical ideas to non-technical stakeholders

Ethical leadership: when to dissent, when to escalate

Unit 2 Policy, Governance & AI Ethics	**09 hours**

How policy is made: legislative, regulatory, and standards processes

Key frameworks: EU AI Act, India's DPDP Act 2023, IEEE standards

Engineers as policy actors: testimony, consultation, design advocacy

Comparative case: Aadhaar — governance lessons for engineers Public interest technology and responsible innovation Ethical theories applied to AI: consequentialism, deontology, virtue ethics Bias, fairness, and representation in algorithmic systems Authentic intelligence: human judgment augmented by AI Accountability gaps: who is responsible when AI fails? Designing for human dignity, autonomy, and informed consen	
Unit 3 Capstone: Integrated Design Challenge	**09 Hours**
Revisiting your Unit 1 problem brief — what has changed? Integrating leadership, policy, and ethics into one design response Stakeholder consultation and co-design methods Prototyping governance structures and technical safeguards Writing for public audiences: op-eds and policy explainers Structuring a policy pitch for decision-makers Visual communication: slides, infographics, and data stories Structured peer review and iteration under time pressure	

Course Outcome	Description
At the end of the course the student will be able to:	
1	Apply authentic intelligence, systems thinking, and leadership models in socio-technical contexts. (Module 1)
2	Demonstrate communication and teamwork skills for presenting technical ideas to stakeholders. (Module 1)
3	Implement AI policy frameworks and governance principles in real-world scenarios. (Module 2)
4	Apply ethical principles to address bias, fairness, and accountability in AI systems. (Module 2)
5	Develop solutions using leadership, policy, and ethical considerations for real-world challenges. (Module 3)

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