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COURSE STRUCTURE (R23)
AND
DETAILED SYLLABUS
(IV YEAR)

MECHANICAL ENGINEERING

For

B.Tech., Four-Year Degree Course

(Applicable for the batches admitted from 2023-24)

LENDI INSTITUTE OF ENGINEERING AND TECHNOLOGY

An Autonomous Institution

Approved by AICTE & Permanently Affiliated to JNTUGV, Vizianagaram

Accredited by NAAC with "A" Grade and NBA (CSE, ECE, EEE & ME)

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B.Tech.–IV-Year I-Semester

S.No.	Course Code	Course Title	Category	L	T	P	Credits
1	R23MEC-PC4101	CAD/CAM	PC	3	0	0	3
2	R23MEC-HM4101	Managerial Skills for Engineers	HM	2	0	0	2
3		**Professional Elective-IV**	PE	3	0	0	3
	R23MEC-PE4101.1	Finite Element Analysis					
	R23MEC-PE4101.2	Industry 4.0: Smart Manufacturing					
	R23MEC-PE4101.3	Electric and Hybrid Vehicles					
	R23MEC-PE4101.4	Industrial Hydraulics &Pneumatics					
	R23MEC-PE4101.5	Design for Manufacturing and Assembly					
4		**Professional Elective-V**	PE	3	0	0	3
	R23MEC-PE4102.1	Computational Fluid Dynamics					
	R23MEC-PE4102.2	Hydrogen and Fuel Cell Technologies					
	R23MEC-PE4102.3	Supply Chain Management					
	R23MEC-PE4102.4	CNC and Adaptive Control					
	R23MEC-PE4102.5	Artificial Intelligence and Machine Learning in Manufacturing					
5	R23OE***-OE****	**Open Elective-III**	OE	3	0	0	3
6	R23OE***-OE****	**Open Elective-IV**	OE	3	0	0	3
7	R23MEC-SC4101	Simulation and Engineering Analysis Laboratory	SEC	1	0	2	2
8	R23MEC-MC4101	Entrepreneurship and Incubation	MC	2	0	0	-
9	R23MEC-I4101	Evaluation of Industry Internship	I	-	-	-	2
Total				**20**	**0**	**2**	**21**

B. Tech–IV-Year II-Semester

S.No.	Course Code	Course Title	Category	L	T	P	Credits
1	R23MEC-PR4201	Internship and Project	**PR**	**-**	**-**	**24**	**12**

Open Electives Courses

Offering Department: Electronics and Communications Engineering

S.No	Course Code	Course Name	L	T	P	Credits
1	R23ECE-OE0001	Basics of Communication Systems	3	0	0	3
2	R23ECE-OE0002	Micro Processors and Interfacing	3	0	0	3
3	R23ECE-OE0003	Digital System Design using Verilog	3	0	0	3
4	R23ECE-OE0004	Fundamentals of Digital Image Processing	3	0	0	3
5	R23ECE-OE0005	Introduction to Internet of Things	3	0	0	3
6	R23ECE-OE0006	Wireless Sensor Networks	3	0	0	3
7	R23ECE-OE0007	Satellite Communication	3	0	0	3
8	R23ECE-OE0008	Fundamentals of Embedded Systems	3	0	0	3

Offering Department: Electrical and Electronics Engineering

S.No	Course Code	Course Name	L	T	P	Credits
1	R23EEE-OE0001	Renewable Energy Sources	3	0	0	3
2	R23EEE-OE0002	Energy Conservation and Management	3	0	0	3
3	R23EEE-OE0003	Electrical Safety & Standards	3	0	0	3
4	R23EEE-OE0004	Utilization of Electrical Energy	3	0	0	3

Offering Department: Computer Science and Engineering & Allied Branches

S.No	Course Code	Course Name	L	T	P	Credits
1	R23CSE-OE0001	Python Programming	3	0	0	3
2	R23CSE-OE0002	Data Structures Using C	3	0	0	3
3	R23CSE-OE0003	Operating System Concepts	3	0	0	3
4	R23CSE-OE0004	Introduction to Java Programming	3	0	0	3
5	R23CSE-OE0005	Database Management Systems Concepts	3	0	0	3
6	R23CSE-OE0006	Unix & Shell Programming	3	0	0	3
7	R23CSE-OE0007	Software Engineering	3	0	0	3
8	R23CSE-OE0008	Introduction to Data mining	3	0	0	3
9	R23CSE-OE0009	Fundamentals of Web Technologies	3	0	0	3
10	R23CSE-OE0010	Fundamentals of Computer Networks	3	0	0	3
11	R23CSE-OE0011	Basics of Cloud Computing	3	0	0	3
12	R23CSE-OE0012	Introduction to Machine Learning	3	0	0	3
13	R23CSE-OE0013	Essentials of Cyber Security	3	0	0	3
14	R23CSE-OE0014	Introduction to React JS	3	0	0	3
15	R23CSE-OE0015	Deep Learning	3	0	0	3
16	R23CSE-OE0016	DevOps	3	0	0	3
17	R23CSE-OE0017	Mobile Computing	3	0	0	3
18	R23CSE-OE0018	Java Full Stack Development	3	0	0	3
19	R23CSE-OE0019	Human Computer Interface	3	0	0	3
20	R23CSE-OE0020	Cryptography and Network Security	3	0	0	3
21	R23CSE-OE0021	Quantum Computing	3	0	0	3
22	R23CSE-OE0022	Big data Analytics	3	0	0	3
23	R23CSE-OE0023	Block Chain Technology	3	0	0	3
24	R23CSE-OE0024	Multimedia Application Development	3	0	0	3

25	R23CSE-OE0025	Mobile Adhoc Networks	3	0	0	3
26	R23CSS-OE0001	Operating Systems	3	0	0	3
27	R23CSS-OE0002	Redhat Linux	3	0	0	3
28	R23CSS-OE0003	Cloud Computing	3	0	0	3
29	R23CSS-OE0004	Distributed Operating System	3	0	0	3
30	R23CIT-OE0001	Basics of computer networks	3	0	0	3
31	R23CIT-OE0002	Cryptography and Network Security	3	0	0	3
32	R23CIT-OE0003	Mobile Computing	3	0	0	3
33	R23CIT-OE0004	Wireless sensor networks	3	0	0	3
34	R23CSM-OE0001	An Introduction to AI	3	0	0	3
35	R23CSM-OE0002	Introduction to Machine Learning using Python	3	0	0	3
36	R23CSM-OE0003	Foundation of Deep Learning for Engineering Applications	3	0	0	3
37	R23CSM-OE0004	Natural Language Processing – Frontiers Approach	3	0	0	3

Note: A student shall select open elective from the above list, excluding those from their respective discipline (i.e., only interdisciplinary courses).

DEPARTMENT OF MECHANICAL ENGINEERING

HONOURS COURSE STRUCTURE AND SYLLABUS

(R23 REGULATION)

MEC (Honors)

Track- I (Manufacturing Technology)							
S.No	**Year & Semester**	**Course Code**	**Subject title**	**L**	**T**	**P**	**C**
1	II-II	R23MEC-HN2201	Material Characterization Techniques	3	0	0	3
2	III-I	R23MEC-HN3101	Product Design and Development	3	0	0	3
3	III-II	R23MEC-HN3201	Advanced Manufacturing Technology	3	0	0	3
4	IV-I	R23MEC-HN4101	Optimization and Reliability	3	0	0	3
5	II Year to IV Year	R23MEC-HM0001	Honors MOOCS-1	0	0	0	3
6	II Year to IV Year	R23MEC-HM0002	Honors MOOCS-2	0	0	0	3
Total							18
Track-II (Thermal Engineering)							
S.No	**Year & Semester**	**Course Code**	**Subject title**	**L**	**T**	**P**	**C**
1	II-II	R23MEC-HN2202	Advanced Fluid Dynamics	3	0	0	3
2	III-I	R23MEC-HN3102	Turbo Machinery	3	0	0	3
3	III-II	R23MEC-HN3202	Design of thermal Systems	3	0	0	3
4	IV-I	R23MEC-HN4102	Cryogenic Engineering	3	0	0	3
5	II Year to IV Year	R23MEC-HM0001	Honors MOOCS-1	0	0	0	3
6	II Year to IV Year	R23MEC-HM0002	Honors MOOCS-2	0	0	0	3
Total							18
Track III (Design Engineering)							
S.No	**Year & Semester**	**Course Code**	**Subject title**	**L**	**T**	**P**	**C**
1	II-II	R23MEC-HN2203	Advanced Mechanism Design	3	0	0	3
2	III-I	R23MEC-HN3103	Engineering Tribology	3	0	0	3
3	III-II	R23MEC-HN3203	Design for Fatigue and Facture	3	0	0	3
4	IV-I	R23MEC-HN4103	Design with advanced Material	3	0	0	3
5	II Year to IV Year	R23MEC-HM0001	Honors MOOCS-1	0	0	0	3
6	II Year to IV Year	R23MEC-HM0002	Honors MOOCS-2	0	0	0	3
Total							18
Track IV (Robotic Engineering)							
S.No	**Year & Semester**	**Course Code**	**Subject title**	**L**	**T**	**P**	**C**
1	II-II	R23MEC-HN2204	Mechanism and Robot Kinematics	3	0	0	3
2	III-I	R23MEC-HN3104	Flexible Manufacturing Systems	3	0	0	3
3	III-II	R23MEC-HN3204	AI and ML for Robotics	3	0	0	3
4	IV-I	R23MEC-HN4104	Autonomous Robot System	3	0	0	3
5	II Year to IV Year	R23MEC-HM0001	Honors MOOCS-1	0	0	0	3
6	II Year to IV Year	R23MEC-HM0002	Honors MOOCS-2	0	0	0	3
Total							18

 # NOTE: In addition to the four subjects mentioned in the table above, students are required to complete two MOOC programs (each with a duration of 12 weeks), as approved by the BOS Chairman

Course Code	Course Name	L	T	P	C
R23MEC-PC4101	**CAD/CAM**	3	0	0	3

Course Objectives: The objectives of the course are to
- Familiarize the important elements of CAD/CAM, geometric representation and transformations.
- Overview the various parametric representations of curves and surfaces in geometric modelling.
- Impart knowledge related to methods and techniques in geometric modeling of solids in CAD.
- Create awareness among the students with numerical control (NC), compute numerical control (CNC) and direct numerical control (DNC) machines.
- Understand the principles and concepts of robotics and various elements of Computer Integrated Manufacturing (CIM).

Course Outcomes: At the end of the course, the student will be able to
- ***Apply*** the basics of geometric transformations to position objects, shape object and change viewing positions of 2D or 3D images. **(L3)**
- ***Construct*** parametric representation of curves and surfaces **(L3)**
- ***Select*** suitable geometric modeling method for building CAD models. **(L3)**
- ***Develop*** the coding system for CNC programming to produce the designated part on the specified CNC machine. **(L3)**
- ***Explain*** the concepts of Group Technology and Computer Integrated Manufacturing in automated systems. **(L2)**

UNIT-I

CAD/CAM: Introduction, hardware and software, I/O devices, benefits. Graphics standards-Neutral file formats–IGES, STEP.
2D and 3D geometric transformations: Translation, scaling, rotation, mirroring, homogeneous transformations, concatenation of transformations, viewing transformations.

Learning Outcomes: At the end of this unit, the student will be able to
- ***explain*** the architecture and components of CAD/CAM systems**(L2)**
- ***apply*** 2D and 3D geometric transformations to manipulate and visualize engineering graphics effectively**. (L3)**

Applications: Automotive Part Design Using CAD/CAM and Neutral File Formats, 3D Model Manipulation in Augmented Reality (AR) for Product Visualization

UNIT-II

Geometric Modelling: Parametric representation: Representation of curves, Hermite curves, Spline, Bezier and B- spline curves in two dimensions; Geometric modelling of surfaces: Surface patch, Coons and bicubic patches, Bezier and B-spline surfaces, sweep surfaces, surface of revolution, blending of surfaces.
Learning Outcomes: At the end of this unit, the student will be able to
- ***explain*** the concepts of parametric representation to curves and surfaces. **(L2)**

- ***construct*** two-dimensional parametric curves such as Hermite, Spline, Bezier, and B-spline curves for use in computer-aided design applications.**(L3)**

Applications: Automotive and Aerospace Surface Design, Medical Prosthetic Design and Bio-Modeling.

UNIT-III

Geometric Modelling of solids: Geometric Modelling of Solids: Wireframe, surface modelling, solid entities, Boolean operations, CSG approach and B-rep of solid modelling, geometric modeling of surfaces.

Learning Outcomes: At the end of this unit, the student will be able to

- ***distinguish*** wireframe, surface and solid modeling **(L3)**
- ***construct*** solid models using Boolean operations, CSG, and B-rep methods in CAD-based product development. **(L3)**

Applications: Design molds, jigs, and fixtures with high precision, Designing smartphones, laptops, and wearable devices use solid and surface modeling to create virtual prototypes.

UNIT- IV

Computer Aided Manufacturing (CAM): Structure of numerical control (NC) machine tools, designation of axes, drives and actuations systems, feedback devices, computer numerical control (CNC) and direct numerical control (DNC), adaptive control system, functions of CN C and DNC systems.

Part Programming: Part programming instruction formats, information codes, preparatory functions, miscellaneous functions (G-codes, M-codes). Tool codes and tool length offset, interpolations canned cycles.

Learning Outcomes: At the end of this unit, the student will be able to

- ***explain*** the architecture and operational principles of NC, CNC, and DNC machine tools. (L2)
- ***develop*** part programs using G-codes, M-codes, tool offsets, and canned cycles.(L3)

Applications: Die and Mould Manufacturing, Automated Tooling in Medical Device Manufacturing

UNIT- V

Group Technology: Part family, coding and classification, production flow analysis, types and advantages. Computer aided processes planning–importance, types.

Computer integrated manufacturing (CIM): Elements of CIM, Virtual Reality (VR), Augmented Reality (AR), Artificial Intelligence (AI) and expert systems in CIM.

Learning Outcomes: At the end of this unit, the student will be able to

- ***understand*** the elements of computer integrated manufacturing (L2)
- ***explain*** the part coding in group technology (L2)

Applications: Group Technology in Engineering Components Manufacturing, Experts systems to simulate production lines and train workers in a risk-free environment.

Text books:

1. P.N. Rao, CAD/CAM: Principles and applications, 3/e, Tata McGraw-Hill, Delhi.
2. Ibrahim Zeid, R.Siva Subramanian, CAD/CAM: Theory and Practice, 2/e, Tata McGraw-Hill, Delhi.

Reference books:

1. Mikell P.Groover, Emory W. Zimmers, CAD/CAM,5/e, Pearson Prentice Hall of India, Delhi.
2. P. Radhakrishnan, S. Subramanyan & V. Raju, CAD/CAM/CIM,3/e, New Age International Publishers
3. Computer Aided Manufacturing, 3/e, Tien Chien Chang, Pearson.

Web References

1. https://nptel.ac.in/courses/112102101
2. https://nptel.ac.in/courses/112102102
3. https://nptel.ac.in/courses/112102103
4. https://nptel.ac.in/courses/112104031

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

S NO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O 1	PS O 2
CO1	3	2	2	1	2	2	-	-	1	1	-	2	2	1
CO2	3	3	2	1	-	2	-	-	1	1	-	2	2	1
CO3	3	2	1	-	2	2	1	-	2	1	-	2	3	2
CO4	3	3	2	-	2	2	1	1	2	2	-	2	3	2
CO5	3	2	2	-	-	2	1	1	2	2	-	2	3	2
CO*	**3**	**3**	**2**	**1**	**2**	**2**	**1**	**1**	**2**	**2**	**-**	**2**	**3**	**2**

** For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-HM4101	**Managerial Skills for Engineers**	3	0	0	3

Course Objectives: The objectives of the course are to

- Provide fundamental knowledge on Management, Administration, Organizational methodologies (L3)
- Equip with the knowledge of long term business value for the organization (L2)
- Explain basics of human resource management & marketing required for organization(L3)
- Analyses the PERT/CPM techniques for better Project Management.(L4)
- Incorporate technology perspectives with Managerial practices(L2)

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

- Apply principles of management & designs of organization in practical world.(L3)
- Realize concepts of business value development for organizational growth.(L2)
- Provided awareness of human resource management and marketing concepts.(L3)
- Develop PERT/CPM Charts for projects of enterprise and estimate time & cost ofproject.(L3)
- Analysis of improved decision making with the implementation of technology in Management(L2)

Unit I:

INTRODUCTION TO MANAGEMENT: Management-Concept -Nature-Functions-Evolution of Management Thought -Principles of Management-Theories of Motivation-Managerial skills-Data driven Decision making-Leadership styles - Interpersonal skills-organizational structures.

Learning Outcomes:
At the end of this unit students will be able to:

- Acquire the techniques, skills and modern engineering tools necessary for engineeringpractice.(L3)
- Apply concepts & principles of management & structures of organization in a practicalworld(L3)

Applications:
Divide the class into two teams' old employees and new joiners and motivate the work environment with respect to excellent management and the supportive.

UNIT II:

BUSINESS VALUE DEVELOPMENT: Business Environment-Building business value through Modernization-Business Analytics- Types-Principles of Value Engineering-Approaches and methods of Business value- Strategies for enhancing Business Value -Corporate Social Responsibility-SWOT analysis of Business

Learning Outcomes:
At the end of this unit students will be able to:
- Measure the value of overall business in the society (L2)
- Analyse the business organization through SWOT analysis (L2)

Application: Analyse a Multi National company's potentialities and business value.

UNIT III:
HUMAN RESOURCES MANAGEMENT & MARKETING MANAGEMENT:
Human Resource Management- Definition and Meaning –Managerial and Operative functions-Job Evaluation and Merit rating- Negotiation skill- Employee performance appraisal.
Marketing Management: Concept- Meaning - Nature-Functions of Marketing- Marketing Mix- Marketing Strategies based on Product Life Cycle-Digital Marketing

Learning Outcomes:
At the end of this unit students will be able to:
- Comprehend the importance of human resources power in the main functional areas (L2)
- Awareness about marketing mix and strategies(L1)

Application: Apply Human resource and marketing aspects in professional decisions through case studies

UNIT IV : PROJECT MANAGEMENT: Project Selection and criteria of choice-Project planning and control- Development of Network- Difference between Program Evaluation Review Technique and Critical Path Method- Identifying critical path-crashing (simple problems).
Learning Outcomes:
At the end of this unit students will be able to:

- Analyze the importance and difficulties associated with the project selection models.(L3)
- Develop PERT/CPM networks for projects of an enterprise and estimate time & cost of project(L3)

Application: Analyze various parameters of the project like critical path, crashing etc. for best cost decisions according to operations of the project.

UNIT V: Technology in Management: AI(Artificial Intelligence) in Management-Finance, Operations,Human Resource- Development Phases of AI for Management Support-Benefits, Challenges and considerations-Best Practices for AI Implementation-Case Examples

Learning Outcomes:
At the end of this unit students will be able to:

- Enhanced decision making skill and efficiency in operations(L2)
- Strategical usage of emerging technologies(L2)

Application: Integrate AI with existing management systems (ERP, CRM).

Text Books:

1. Management Science by Aryasri; Publisher: Tata McGraw Hill, 2009
2. L.M. Prasad, Principles and Practice of Management.

Reference Books:

1. Robins, Stephen P., *Fundamentals of Management,* Pearson, India.
2. Kotler Philip & Keller Kevin Lane: Marketing Management 12/e, PHI, 2007
3. Koontz &Weihrich: *Essentials of Management*, 6/e, TMH, 2007
4. Valuing a Business, 5th Edition : The Analysis and Appraisal of Closely Held Companies, Shannon P.Pratt
5. Artificial Intelligence Concepts for Management, Paperback, Katzan Harry Jr, 2023

Web links:

1. www.managementstudyguide.com
2. www.citehr.com
3. www.nptel.ac.in/courses/
122106032
4.https://nptel.ac.in/courses
/110/106/110106145/
5. www.btechguru.com/courses--nptel--basic-course

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

SNO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2	PSO 1	PSO 2
CO1	-	-	-	-	-	2	2	1	1	-	-	1	-	1
CO2	1	1	-	-	-	1	1	-	-	-	1	2	-	1
CO3	-	2	-	-	-	2	2	2	-	1	2	1	-	1
CO4	-	2	1	-	-	1	1	-	1	-	2	1	-	1
CO5	-	2	1	-	-	1	-	2	-	-	-	1	-	1
CO*	1	2	1	-	-	1	2	2	1	1	2	1	0	1

** For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-PE4101.1	**Finite Element Analysis (Professional Elective-IV)**	3	0	0	3

Course Objectives: The objectives of the course are

- To introduce the fundamental principles and procedures involved in finite element analysis.
- To understand the underlying theory and characteristics of finite elements used in modeling engineering structures.
- To explain the formulation and application of finite elements for structural analysis using truss and beam elements.
- To apply finite element methods for solving two-dimensional problems involving triangular, axisymmetric, and quadrilateral elements.
- To demonstrate the application of finite element techniques in solving heat transfer problems and dynamic system analysis.

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

- ***Explain*** the fundamental principles of finite element analysis, stress-strain relations, and various modeling techniques used in the formulation of finite element equations. **(L2).**
- ***Apply*** finite element procedures to determine stresses and strains in one-dimensional structural elements like bars, including the development of stiffness matrices, load vectors, and displacement calculations. **(L3)**
- ***Analyze*** the structural behaviour of truss and beam elements using finite element formulations to calculate stiffness matrices, stress-strain responses, and support reactions. **(L4)**
- ***Apply*** the finite element formulation techniques to solve two-dimensional engineering problems using triangular, axisymmetric, and quadrilateral elements. **(L3)**
- ***Analyze*** the application of finite element methods for solving heat transfer and dynamic problems by evaluating element matrices, boundary conditions, and system responses. **(L4)**

Unit I

Introduction: Introduction to finite element methods for solving field problems, Stress and equilibrium, Boundary conditions, Strain-Displacement relations, Stress- strain relations for 2D and 3D Elastic problems. Potential energy and equilibrium, The Rayleigh-Ritz method, Formulation of Finite Element Equations.

Learning outcomes: After completion of this unit the students will be able to

- ***understand*** the numerical methods involved in Finite Element theory. (L2)
- ***understand*** the concepts behind variational methods and weighted residual methods in FEM. (L2)
- ***understand*** direct and formal (basic energy and weighted residual) methods for deriving finite element equations. (L2)

Applications: Structural Analysis of Bridges or Aircraft Wings, Thermal Analysis in Electronics

Unit II
One-Dimensional Elements: Bar, trusses, beams and frames, displacements, stresses and temperature effects.
Learning outcomes:

After completion of this unit the students will be able to

1. ***develop*** element characteristic equation procedure and generation of global stiffness equation will be applied. (L3)
2. ***apply*** Suitable boundary conditions to a global structural equation, and reduce it to a solvable form. (L3)
3. ***solve*** axially loaded bar Problems. (L3)

Applications: Design of Transmission Towers, Railway Track Analysis.

Unit III
Analysis of Trusses: Finite element modelling, coordinates and stiffness Matrix for plane truss element. Assembly of global stiffness matrix and load vector, finite element equations, treatment of boundary conditions, stress, strain and support reaction calculations.
Analysis of Beams: Boundary conditions, Load vector, Hermite shape functions and simple problems.

Learning Outcomes: After completion of this unit the students will be able to

- ***Understand*** the use of the basic finite elements for structural applications using truss and beam. (L2)
- ***Solve*** truss and beam problems. (L3)

Applications: Roof Truss Design in Warehouses, Bridge Beam Analysis

Unit IV
Two Dimensional Problems: Finite Element Modeling, Constant Strain Triangle (CST) Element Stiffness, Force terms, Stress calculation, Problem modeling and boundary conditions. Plane Stress and plane Strain Problems using CST Element. Problems on iso parametric formulation of 4-noded quadrilateral element.
Numerical Integration: Gaussian quadrature one point, two point and three-point formulae, 2D integrals.
Learning Outcomes: After completion of this unit the students will be able to

- ***apply*** standard formulation techniques to solve 2D problems using triangular and quadrilateral finite elements (L3).
- ***solve*** plane stress conditions, axisymmetric and Quadrilateral Element Problems.(L3)

Applications: Design and Analysis of Aircraft Wings, Stress Analysis of Dam Structures

Unit V
One Dimensional Heat transfer Problems: Equilibrium equations, heat conduction in plane walls, heat transfer analysis of fins, finite element formulation, simple problems.
Dynamic analysis: Formulation of finite element model, element consistent and lumped mass matrices, evaluation of eigen values and eigenvectors, free vibration analysis.
Learning Outcomes: After completion of this unit the students will be able to

- ***understand*** the application and use of the Finite Element Methods for heat transfer problems. (L2)

- ***solve*** the heat transfer problems. (L3)
- ***understand*** problems involving dynamics using Finite Element Methods. (L2)
- ***apply*** suitable boundary conditions to a global equation for dynamic problems and
- ***solve*** them Eigenvalues, Eigen Vectors and vibration analysis for stepped bar and beam elements. (L3)

Applications: Thermal Management in Electronic Devices, Vibration Analysis of Automotive Components

Textbooks

1. Chandrupatla T. R., Finite Elements in engineering. PHI, 2nd Edition.
2. S.S. Rao. The Finite Element Methods in Engineering. Elsevier Butterworth – Heinemann, 2/e, Fifth edition.

References

1. J N Reddy, An introduction to the Finite Element Method, McGraw – Hill, New York, 4 th edition
2. R D Cook, D S Malkus and M E Plesha, Concepts and Applications of Finite Element Analysis, 3rd Edition, John Wiley, New York, 3 rd edition
3. K J Bathe. Finite Element Procedures in Engineering Analysis. Prentice-Hall. Englewood Cliffs, 2 nd edition
4. T J R Hughes, the Finite Element Method, Prentice-Hall, Englewood Cliffs, NJ, 3rd Edition.
5. C Zienkiewicz and R L Taylor. the Finite Element Method, McGraw Hill, 3rd Edition.

Web resources:

1. https://archive.nptel.ac.in/courses/112/105/112105308/
2. https://archive.nptel.ac.in/courses/112/105/112105308/
3. https://www.youtube.com/watch?v=MldJ6WHCsvQ
4. https://www.youtube.com/watch?v=KR74TQesUoQ
5. https://www.youtube.com/watch?v=1M9mKTm9e2w

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PO12	PSO 1	PSO 2
CO1	3	3	3	2	2	1	-	-	-	-	-	2	3	-
CO2	3	3	3	2	3	1	-	-	-	1	1	3	2	-
CO3	3	3	3	2	3	1	-	-	-	1	1	1	3	2
CO4	3	3	3	2	3	1	-	-	-	1	1	2	3	1
CO5	3	3	2	2	2	1	1	1	-	1	1	2	3	2
CO*	3	3	2	2	3	1	1	1	-	1	1	2	3	2

* *For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-PE4101.2	**INDUSTRY 4.0: Smart Manufacturing (Professional Elective-IV)**	3	0	0	3

Course Objectives: The objectives of the course are to

- To understand the fundamental concepts and technologies of Industry 4.0
- To explore digital transformation and flexible production systems in modern industries
- To study the implementation of Industry 4.0 technologies in smart manufacturing
- To analyze the impact of Industry 4.0 on sustainability and industrial environments
- To understand smart machines and digital industry transformation systems

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

- ***Explain*** the concepts and drivers of Industry 4.0 and digital transformation (L2)
- ***Analyze*** digital transformation strategies and change management in industries (L4)
- ***Apply*** Industry 4.0 concepts for smart manufacturing systems (L3)
- ***Explain*** Digital Twin technology and sustainability applications in Industry 4.0 (L2)
- **Analyze** smart machines and enterprise-level digital manufacturing systems (L4)

UNIT – I

Introduction to Industry 4.0, overview and evolution in various industries, opportunities for digital transformation, traditional versus smart manufacturing, key concepts and drivers for digital transformation, industrial revolutions (1.0 to 4.0).

Learning Outcomes: After completion of this unit the students will be able to:

- ***explain*** the evolution and concepts of Industry 4.0 (L2)
- ***describe*** about digital transformation (L2)

Applications: Smart factories, Additive manufacturing systems, Cyber-physical production systems

UNIT – II

Risk of data security, IT infrastructure, legacy machines, competitive edge, increased work safety, flexible production, customer satisfaction, transforming customer experience, operational processes and business models, change management and theories, vision and strategies.

Learning Outcomes: After completion of this unit the students will be able to:

- ***analyze*** digital transformation strategies and implementation challenges (L4)
- ***explain*** predictive maintenance and collaborative manufacturing systems (L2)

Applications: Predictive maintenance systems, AR-based maintenance training, Collaborative robotic systems

UNIT – III

Implementing Industry 4.0 for smart manufacturing, typical industrial setup, implementation strategies, industry-wise pain points and challenges, key performance indicators in industries, connected manufacturing solutions, connected supply chain systems, manufacturing analytics concepts, examples, and use cases.

Learning Outcomes: After completion of this unit the students will be able to:

- ***apply*** Industry 4.0 concepts in smart manufacturing systems (L3)
- ***apply*** manufacturing analytics and connected supply chain systems (L3)

Applications: Connected manufacturing, Smart supply chains, Manufacturing analytics systems

UNIT – IV

Impact of Industry 4.0 on environment and sustainability, environmental management in Industry 4.0, technologies for environmental management, challenges in implementing Industry 4.0 for sustainability, introduction to Digital Twins and their functions, Digital Twins built on IoT platforms with applications in automotive industries, future trends.

Learning Outcomes: After completion of this unit the students will be able to:

- ***explain*** environmental sustainability concepts in Industry 4.0 (L2)
- ***understand*** Digital Twin implementation and applications in smart manufacturing (L2)

Applications: Digital Twin-based manufacturing, Sustainable industrial systems, automotive smart production

UNIT – V

Introduction to smart machines, evolution of smart machines, building blocks of smart machines, sensors and signal processing, controllers in smart machines, smart machines and future technologies, product lifecycle management, material requirement planning, manufacturing process management, manufacturing execution systems, enterprise resource planning.

Learning Outcomes: After completion of this unit the students will be able to:

- ***explain*** smart machine technologies and digital manufacturing systems (L2)
- ***analyze*** enterprise-level manufacturing management systems (L4)

Applications: Smart manufacturing systems, Enterprise resource planning, intelligent industrial automation

Text Books

1. Jean-Claude Andre – Industry 4.0, Wiley-ISTE.
2. Diego Galar Pascual, Pasquale Daponte, Uday Kumar – Handbook of Industry 4.0 and SMART Systems, Taylor & Francis.

Reference Books

1. Miller M – The Internet of Things: How Smart TVs, Smart Cars, Smart Homes, and Smart Cities are Changing the World, Pearson Education.
2. Pengwei Du and Ning Lu – Energy Storage for Smart Grids: Planning and Operation for Renewable and Variable Energy Resources, Academic Press.
3. Hossam A. Gabbar – Smart Energy Grid Engineering, Academic Press.

4. Mini S. Thomas, John Douglas McDonald – Power System SCADA and Smart Grids, CRC Press.

COURSE OUTCOMES VS POs MAPPING
[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

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

** For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-PE4101.3	**Electric and Hybrid Vehicles (Professional Elective-IV)**	3	0	0	3

Course Objectives: The objectives of the course are

- Familiarize the fundamentals of conventional and hybrid electric vehicle components.
- Understand the configurations and working of hybrid and electric drive-trains.
- Understand the architecture, operation and energy management of PHEVs
- Study and understand different power converters used in hybrid and electrical vehicles.
- Familiarize with different batteries and other energy storage systems.

Course outcomes: After completion of the course, the student will be able to:

- ***Understand*** the fundamentals of conventional and hybrid electric vehicle components.(L2)
- ***Describe*** hybridization of power sources in hybrid electric vehicles. (L2)
- ***Apply*** the principles of power management and fuel economy to optimize the PHEV performance.(L3)
- ***Explain*** the working principle of power electronics in hybrid vehicles. (L2)
- ***Describe*** the different battery technologies and other energy storage systems. (L2)

UNIT–I:

Introduction: Fundamentals of vehicle, components of conventional vehicle and propulsion load, drive cycles and drive terrain; concept of electric vehicle and hybrid electric vehicle; history of hybrid vehicles, advantages and applications of electric and hybrid electric vehicles, different motors suitable for of electric and hybrid electric vehicles.

Learning Outcomes: After completion of this unit the students will be able to:

- ***differentiate*** conventional and hybrid vehicles (L2).
- ***explain*** the advantages of hybrid vehicles. (L2).

Applications: Optimization of fuel usage in hybrid vehicles through combined engine–motor operation, Monitoring of EV battery performance across varying terrains and traffic conditions.

UNIT–II:

Architectures of Hybrid, Plug-in Hybrid, Fuel Cell and Electric Vehicles:

Hybrid Electric Drive-trains: Architectures of HEVs, Series and parallel HEVs complex HEVs. Plug-in hybrid vehicle, constituents of PHEV, comparison of HEV and PHEV- Fuel Cell vehicles and its constituents.

Electric Drive-trains: Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies.

Learning Outcomes: After completion of this unit the students will be able to:

- ***illustrate*** architectures of hybrid vehicles the hybridization of power sources in hybrid vehicles. (L2).
- ***explain*** the working of fuel cell electric vehicles. (L2)

Applications: Using HEVs and PHEVs in public transport to reduce fuel use and emissions, Optimizing energy use and range in electric vehicles and buses for urban operations.

UNIT–III:

Plug-in Hybrid Electric Vehicle PHEVs and EREVs blended PHEVs, PHEV Architectures, equivalent electric range of blended PHEVs; Fuel economy of PHEVs, power management of PHEVs, end-of-life battery for electric power grid support, vehicle to grid technology(V2G), PHEV battery charging.

Learning Outcomes: After completion of this unit the students will be able to:

- ***illustrate*** the hybrid vehicle architectures and its functions. (L2)
- ***discuss*** the methods of fuel economy of PHEVs. (L2)

Applications: Optimizing fuel economy by managing the switch between electric and combustion power in PHEVs, Using PHEV batteries to support the grid during peak demand through Vehicle-to-Grid (V2G) technology.

UNIT–IV:

Power Electronics in HEVs: Rectifiers used in HEVs, voltage ripples, Buck converter used in HEVs, non- isolated bidirectional DC-DC converter, voltage source inverter, current source inverter, isolated bidirectional DC-DC converter, PWM rectifier in HEVs, EV and PHEV battery chargers.

Learning Outcomes: After completion of this unit the students will be able to

- ***discuss*** the significance of power electronics in hybrid and electric vehicles. (L2)
- ***explain*** the working of bidirectional converters used in hybrid electric vehicles. (L2)

Applications: Using a bidirectional DC-DC converter in HEVs to optimize energy flow between the battery and motor, Employing PWM rectifiers and battery chargers for efficient and quick charging of EVs and PHEVs.

UNIT–V:

Battery and Storage Systems: Energy storage parameters; lead acid, li-ion and Ni-MH batteries, ultracapacitors, flywheels- superconducting magnetic storage system; pumped hydroelectric energy storage; compressed Air energy storage-storage heat; energy storage as an economic resource.

Learning Outcomes: After completion of this unit the students will be able to

- ***differentiate*** electrochemical batteries and Supercapacitors.(L2)
- ***identify*** key energy storage systems and their economic significance in power management. (L2)

Applications: Battery selection in EVs: Selecting Li-ion or Ni-MH batteries for EVs based on battery cost and performance, Supporting the power grid with pumped hydro or compressed air energy storage systems.

Text Books:

1. Ali Emadi, Advanced Electric Drive Vehicles, 1st Edition, CRC Press.
2. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, 2nd Edition, CRC Press.

Reference Books:

1. Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press.
2. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley.
3. H.Partab: Modern Electric Traction-DhanpatRai & Co.

Web link: https://archive.nptel.ac.in/courses/108/103/108103009/

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

CO	PO1	PO 2	PO 3	PO4	PO 5	PO 6	PO7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	3	2	2			2	2	-	-	-		2	2	1
CO2	3	3	3	2	2	2	3	-	-	-	3	2	2	1
CO3	3	3	3	2	3	2	3	-	-	-	3	2	2	1
CO4	3	2	2	2	2	2	3	-	-	-		2	2	1
CO5	3	2	2	2	1	2	3	-	-	-		2	2	1
CO*	**3**	**2**	**2**	**2**	**2**	**2**	**3**	**-**	**-**	**-**	**3**	**2**	**2**	**1**

** For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-PE4101.4	**Industrial Hydraulics & Pneumatics (Professional Elective-IV)**	3	0	0	3

Course objective: The objectives of the course are to

- Understand the basic fundamentals of fluid power system
- Explain the working principles of hydraulic actuators and hydraulic motors
- Understand the characteristics of hydraulic circuit elements
- Explain basic concepts of pneumatic system and its components
- Describe the servo systems and its characteristics

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

- ***Explain*** the fundamentals of fluid power systems, fluid properties, hydraulic symbols, and working principles of pumps. (L2)
- ***Analyze*** the construction, working, and performance of hydraulic actuators and solve numerical problems related to hydraulic motors and circuits. (L4)
- ***Interpret*** the functions and working principles of hydraulic control valves, accumulators, and intensifiers. (L2)
- ***Illustrate*** the components, working principles, and circuit representation of pneumatic and electro-pneumatic systems. (L2)
- ***Evaluate*** the performance of pneumatic/electro-pneumatic circuits, servo systems, and diagnose faults using troubleshooting methods. (L3)

UNIT – I

Fundamentals of Fluid Power Systems-Introduction-types-advantages-disadvantages & applications-fluid characteristics-terminologies used in fluid power-hydraulic symbols-hydraulic systems and components-sources-pumping theory-gear, vane & piston pumps.

Learning Outcomes: At the end of this unit, the student will be able to

- ***understand*** Fundamentals of Fluid Power Systems. (L2)
- ***explain*** the fluid characteristics for different applications (L2)

Applications: Excavators and cranes, Hydraulic presses, Automobile braking systems.

UNIT-II

Fluid Power Actuators: Introduction-hydraulic actuators-hydraulic cylinders-types, construction, specifications and special types. Hydraulic motors- working principle-selection criteria for various types-hydraulic motors in circuits- formulae-numerical problems.

Learning Outcomes: At the end of this unit, the student will be able to

- ***describe*** construction of hydraulic actuators.(L2)
- ***explain*** working principle of hydraulic motors. (L2)
- ***evaluate*** the performance of hydraulic motors in circuits (L3)

Applications: Forklifts and dump trucks, Industrial conveyors, Robotic arms

UNIT-III
Hydraulic control elements-direction control valve-check valve-pressure control valve-relief valve-throttle valve-temperature & pressure compensation-locations of flow control valve. Accumulators & intensifiers-types-working principle

Learning Outcomes: At the end of this unit, the student will be able to
- ***understand*** hydraulic direction control valves. (L2)
- ***describe*** types of Accumulators & intensifiers. (L2)
- ***explain*** working principle of Accumulators & intensifiers(L2)

Applications: Machine tool automation systems, Hydraulic safety systems (relief valves), Energy storage in hydraulic accumulators.

UNIT-IV
Pneumatic systems-Introduction-symbols used-concepts & components -types & specifications of compressors-compressed air behaviour-understanding pneumatic circuits- direction control valves Electro pneumatics- Introduction-Pilot operated solenoid valve- electrical connections to solenoids-electro pneumatic circuit switches-relays-solenoids-P.E converter-concept of latching

Learning Outcomes: At the end of this unit, the student will be able to
- ***explain*** working of Pneumatic system components. (L2)
- ***explain*** direction control valves. (L2)
- ***explain*** P.E converter and concept of latching. (L2)

Applications: Industrial assembly lines , Air brake systems in vehicles , CNC machine automation.

UNIT-V
Applications-servo systems-introduction-closed loop, hydro-mechanical and electro hydraulic–conventional and proportional valves-characteristics of proportional and servo valves- PLC applications in fluid power – selected pneumatic / electro pneumatic circuit problems – failure and trouble shooting in fluid power systems.

Learning Outcomes: At the end of this unit, the student will be able to
- ***explain*** characteristics of proportional and servo valves. (L2)
- ***explain*** failure and trouble shooting in fluid power systems.(L2)

Applications: Aircraft control systems , PLC-based automation systems , Missile and aerospace servo system.

Text Books:
1. Introduction to Hydraulics and Pneumatics by S. Ilango and V.Soundararajan, PHI, NewDelhi, 3rd edition
2. Hydraulics and pneumatics by T. Jagadeesha, Dreamtech press, 1st edition

Reference Books:
1. Oil Hydraulic Systems, S.R .Majumdar, McGraw Hill Companies, 1st edition
2. Pneumatic Systems: Principles and Maintenance, Majumdar, McGraw Hill, 1st edition.

3. Industrial Hydraulics and Pneumatics by P.K Chandrasekara, P.B. Mali, Tech Neo Publications llp, Pune, 1st edition

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

CO	PO1	PO 2	PO 3	PO4	PO 5	PO 6	PO7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	3	1	–	–	–	–	–	–	–	–	–	–	2	1
CO2	3	3	2	2	1	–	–	–	–	–	–	–	3	2
CO3	3	2	–	–	–	–	–	–	–	–	–	–	2	1
CO4	3	2	1	–	1	–	–	–	–	1	–	–	2	1
CO5	3	3	2	2	2	–	–	–	–	1	1	1	3	2
CO*	**3**	**3**	**2**	**2**	**2**	**-**	**-**	**-**	**-**	**1**	**1**	**1**	**3**	**2**

* *For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-PE4101.5	**Design for Manufacturing and Assembly (Professional Elective-IV)**	3	0	0	3

Course Objectives: The objectives of the course are

- Provide an understanding of design philosophies, steps in the design process, and rules for manufacturability and economical production.
- Familiarize students with material selection criteria and the interrelationship between materials and manufacturing processes.
- Enable students to apply design guidelines for machining and metal joining processes to improve manufacturing ease and quality.
- Develop knowledge in designing components suitable for casting, forging, extrusion, and sheet metal forming based on manufacturing constraints.
- Introduce principles of assembly design and environmental considerations, including eco-efficiency and life cycle analysis, in product development.

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

- ***Apply*** the key steps in the design process and general rules to enhance manufacturability in product development. *(L3)*
- ***Analyze*** the relationship between material selection, manufacturing processes, and product performance to support economical production decisions. *(L4)*
- ***Evaluate*** design considerations for machining, casting, forging, and sheet metal processes using practical examples. *(L5)*
- ***Modify*** component designs using established guidelines to improve ease of machining, welding, and assembly. *(L3)*
- ***Develop*** suitable assembly features for automated production by applying liaison diagrams and compliance analysis techniques. *(L5)*

UNIT- I

Introduction: Design philosophy – steps in design process – general design rules for manufacturability – basic principles of designing for economical production – creativity in design, application of linear & non-linear optimization techniques.

Materials: Selection of materials for design – developments in material technology – criteria for material selection – material selection interrelationship with process selection – process selection charts.

Applications: Automobile component design, Aerospace, Electronics packaging.

Learning outcomes: After completion of this unit the students will be able to:

- ***apply*** the steps in the design process and general design rules to enhance manufacturability and economical production (L3).
- ***understand*** the relationship between material selection and process selection using process selection charts for effective design decisions. *(L2)*

UNIT-II

Machining process: Overview of various machining processes – general design rules for

machining - dimensional tolerance and surface roughness – design for machining – ease – redesigning of components for machining ease with suitable examples, general design recommendations for machined parts.
Metal joining: Appraisal of various welding processes, factors in design of weldments – general design guidelines – pre and post treatment of welds – effects of thermal stresses in weld joints – design of brazed joints.

Applications: Crankshafts, pistons, hull assembly, surgical instruments and implants

Learning outcomes: After completion of this unit the students will be able to:

- ***apply*** general design guidelines to evaluate weldment designs and understand the impact of thermal stresses and treatments on joint performance. *(L3)*
- ***analyze*** the influence of general design rules, dimensional tolerances, and surface finish on the manufacturability of machined components. *(L4)*

UNIT-III
Metal casting: Appraisal of various casting processes, selection of casting process, - general design considerations for casting – casting tolerances – use of solidification simulation in casting design – product design rules for sand casting.
Forging: Design factors for forging – closed die forging design – parting lines of dies – drop forging die design – general design recommendations.

Applications: Landing gear, turbine discs, valve bodies, pump housings.

Learning outcomes: After completion of this unit the students will be able to:

- ***analyze*** key design factors in forging processes, including die design, parting lines, and general recommendations for closed-die and drop forging. *(L4)*
- ***evaluate*** design considerations and tolerances for various casting processes and apply product design rules for sand casting using simulation insights. *(L5)*

UNIT-IV
Extrusion and sheet metal work: Design guidelines for extruded sections – design principles for punching, blanking, bending, and deep drawing – Keeler Goodman forming line diagram – component design for blanking.

Applications: Car body panels, HVAC ductwork, Aerospace structural components, Electronics enclosures

Learning outcomes: After completion of this unit the students will be able to:

- ***apply*** design guidelines to develop suitable extruded sections for efficient manufacturing. *(L3)*
- ***apply*** forming line diagrams and design principles to modify components for blanking, bending, and deep drawing operations. *(L3)*

UNIT-V
Assembly: Compliance analysis and interference analysis for the design of assembly – design and development of features for automatic assembly – liaison diagrams. Environment: Introduction to environment; motivations for environment principles of environment- eco-efficiency, product life cycle perspective, environment tools and processes, environment

design guidelines.

Applications: Solar panel production, Recyclable packaging design, Modular construction assembly.

Learning outcomes: After completion of this unit the students will be able to:

- ***develop*** assembly features using compliance and interference analysis, and apply liaison diagrams for automated assembly design. *(L5)*
- ***analyze*** environmental design principles such as eco-efficiency and life cycle perspective to integrate sustainability into product development. *(L4)*

Text Books:

1. A K Chitale and R C Gupta, "Product Design and Manufacturing", First Edition, PHI, New Delhi.

Reference Books:

1. Boothroyd G, "Product design for Manufacture and Assembly", First Edition, Marcel Dekker Inc, New York.
2. GeorgeE Deiter, "Engineering Design", Second Edition, Mc Graw Hill International.

Web Sources:

- https://www.dfma.com
- https://ocw.mit.edu/courses/mechanical-engineering/2-009-product-engineering-process-fall-2009/
- https://nptel.ac.in/Design of manufacturing and assembly
- https://www.engineeringtoolbox.com

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

CO	PO1	PO 2	PO 3	PO4	PO 5	PO 6	PO7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	3	-	1	-	-	-	-	-	-	-	-	-	2	-
CO2	3	2	2	-	-	-	-	-	-	-	-	-	2	-
CO3	3	2	3	-	-	-	-	-	-	-	-	-	3	-
CO4	3	2	3	2	-	-	-	-	-	-	-	-	3	2
CO5	2	-	3	2	2	-	-	-	-	-	-	2	3	2
CO*	**3**	**2**	**3**	**2**	**2**	**-**	**-**	**-**	**-**	**-**	**-**	**2**	**3**	**2**

** For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-PE4102.1	**Computational Fluid Dynamics (Professional Elective-V)**	3	0	0	3

Course Objectives: The objectives of the course are

- To Familiarize with CFD analysis for fluid flow and heat transfer problems.
- To impart knowledge of numerical methods including FDM, FEM, and FVM.
- To develop the ability to mathematical model physical phenomena in fluid mechanics.
- To explore the influence of boundary and initial conditions on the numerical solutions of conduction and convection heat transfer problems.
- To Implement the integral and differential forms of fluid flow governing equations to solve fluid flow problems

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

- ***Classify*** the mathematical models for FEM, FDM, FVM techniques (L2)
- ***Apply*** the mathematical and computational methods for fluid flow simulations (L3)
- ***Apply*** numerical methods and grid generation techniques to discretize and solve fluid flow problems (L3)
- ***Analyze*** the finite difference methods to solve steady and transient heat conduction problems in rectangular geometries (L4)
- ***Identify*** the appropriate numerical method to solve 1D and 2D problems in steady and
- Transient heat transfer conditions (L3)

UNIT - I

INTRODUCTION: Computational Fluid Dynamics as a Research and Design Tool, Applications of Computational Fluid Dynamics, Need for Computational Fluid Dynamics – Different Numerical/CFD techniques – FDM, FEM, FVM, Governing Equations of Fluid Dynamics, Control Volume, Substantial Derivative, Divergence of Velocity, Continuity Equation, Momentum Equation and Energy Equation

Applications: Aerospace Engineering, Automotive Design, HVAC Systems, Biomedical Engineering, Marine Engineering, Turbo machinery.

Learning Outcomes: At the end of the unit, student will be able to

- ***describe*** the scope and applications of CFD in engineering (L2)
- ***understand*** the significance of the continuity, momentum, and energy equations to solve in computational fluid dynamics (L2)

UNIT - II

MATHEMATICAL DESCRIPTION OF PHYSICAL PHENOMENON: Introduction, Governing differential equations, Nature of the coordinates, Classification of Quasi-Linear

Partial Differential Equations - Hyperbolic Equations, Parabolic Equations, Elliptic Equations, Time Dependent methods.

Applications: Weather prediction Models, Wave Propagation, Thermal system simulation, Seismic Analysis.

Learning Outcomes: At the end of the unit, student will be able to
- ***understand*** the nature and classification of PDEs (Elliptic, Parabolic, Hyperbolic)(L2)
- ***apply*** classification techniques for solving time-dependent and steady problems(L3)

UNIT – III

BASICS ASPECTS OF DISCRETIZATION: Introduction, Explicit and Implicit Approaches, Errors and Stability Analysis, Method of deriving discretization equation – Taylor formulation, Grid Generation- Algebraic Grid Generation, Elliptic Grid Generation, Hyperbolic Grid Generation, Parabolic Grid Generation, Difference between structured and unstructured grids –Advantages /disadvantages, Cell Centred and Nodal point Approaches.

Applications: Mesh Design in CFD software, Heat Exchanger Design, Combustion Simulation, Multi physics Simulations

Learning Outcomes: At the end of the unit, student will be able to
- ***apply*** explicit and implicit methods to solve time-dependent problems (L3)
- ***compare*** algebraic, elliptic, hyperbolic and parabolic grid generation methods (L2)

UNIT – IV

HEAT CONDUCTION: Finite Difference Applications in conduction and convection heat transfer– Heat conduction, steady and transient heat conduction in a rectangular geometry.

Applications: Thermal Insulation Design, Electronics Cooling, Battery Thermal Management, Casting and Welding

Learning Outcomes: At the end of the unit, student will be able to
- ***apply*** finite difference methods to solve steady and unsteady 1D & 2D heat conduction (L3)
- ***examine*** the influence of various boundary and initial conditions on the numerical solutions of heat conduction and convection problems (L4)

UNIT - V

FLUID FLOW EQUATIONS:

Introduction, The fluid-flow equations - Integral/control-volume form of the governing equations and Differential forms of the governing equations – Other differential equations of fluid flow, Compressible and incompressible flow, Non-dimensionalisation, Finite Difference Solutions of 2D Viscous Incompressible flow problems –Vorticity and Stream Function Formulation.

Applications: Internal flow simulation, External flow problems, Pollution Dispersion, Turbo-Machinery

Learning Outcomes: At the end of the unit, student will be able to

- ***solve*** compressible and incompressible flow problems with Finite difference method (L3)
- ***derive*** the Navier-Stokes equations and associated auxiliary equations used in fluid dynamics. (L3)

Text Books:
1. John. D. Anderson, Computational fluid dynamics – The basics with Applications,6th Edition. Mc Graw Hill.
2. Dr.Atul Sharma, Introduction to Computational Fluid Dynamics: Developments, Applications and Analysis, 1st Edition, Athena Academic and Wiley (UK).

Reference Books :
1. K.A.Hoffman and Steve T Chiang, Computational Fluid Dynamics, Vol.I, 4th Edition, Engineering Education System Publications.
2. Suhas V Patankar, Numerical heat transfer and Fluid flow, 1st Edition, Taylor and Francis.

WEB SOURCES:
1. NPTEL-Computational fluid dynamics (IIT-Kharagpur) https://nptel.ac.in/courses/112/105/112105254/
2. NPTEL-Computational fluid dynamics using finite volume method (IIT-Madras) https://nptel.ac.in/courses/112/106/112106294/

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

CO	PO1	PO 2	PO 3	PO4	PO 5	PO 6	PO7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	3	3	2	2	2	-	-	-	-	-	-	3	3	3
CO2	3	3	2	2	2	1	-	-	-	-	-	3	3	3
CO3	3	3	2	2	2	2	2	-	-	-	-	3	3	3
CO4	3	3	2	2	2	2	2	-	-	-	-	3	3	3
CO5	3	3	2	2	2	2	2	-	-	-	-	3	3	3
CO*	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**-**	**-**	**-**	**-**	**3**	**3**	**3**

* *For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-PE4102.2	**Hydrogen and Fuel Cell Technologies (Professional Elective-V)**	3	0	0	3

Course objectives: The objectives of the course are to

- Familiarize hydrogen fundamentals, production, sustainability and its role as clean energy.
- Explain hydrogen generation and storage technologies.
- Describe fuel cell principles, types, development history and its potential applications.
- Apply principles of fuel cell electrochemistry to evaluate its performance and efficiency
- Analyze fuel cell system design, integration, safety, cost and renewable hydrogen utilization.

Course Outcomes: After completion of the course, the student will be able to:

- ***Describe*** hydrogen properties, sustainability, production methods and its role as an energy carrier.(L2)
- ***Explain*** various hydrogen generation and storage methods including conventional, renewable and emerging technologies.(L2)
- ***Illustrate*** the history, types of fuel cells, applications and their role as an electrochemical engines.(L2)
- ***Apply*** electro chemical principles to analyze fuel cell performance, efficiency and voltage losses.(L3)
- ***Apply*** fuel cell system design principles to assess integration, safety, cost, and renewable hydrogen use.(L3)

Unit-I

Introduction: Basic properties of hydrogen, engineering thermodynamics, hydrogen and environment, hydrogen and sustainability, hydrogen production methods, green hydrogen sources, hydrogen as an energy carrier, historical background and current applications.

Learning Outcomes: After completion of this unit the students will be able to

- ***explain*** hydrogen properties, environmental impact and sustainability.(L2)
- ***identify*** green hydrogen sources, its role as an energy carrier and its current applications.(L2)

Applications: Hydrogen production for sustainable energy use, Green hydrogen serves as a clean energy source for transport, industry and power sectors.

Unit-II

Hydrogen Generation Methods: Steam methane reforming, electrolysis (alkaline, PEM, and solid oxide electrolysis), coal/biomass gasification, solar and wind-based hydrogen production, emerging hydrogen generation technologies.

Hydrogen Storage Techniques: Compressed gas storage, liquid hydrogen storage, chemical storage (hydrogenation, metal hydrides) and emerging hydrogen storage technologies.

Learning Outcomes: After completion of this unit the students will be able to:

- ***explain*** hydrogen generation methods and renewable sources.(L2)
- ***describe*** hydrogen storage techniques and methods.(L2)

Applications: Utilization of electrolysis-based hydrogen in fuel cell electric vehicles (FCEVs), Application of metal hydride storage in backup power and portable energy systems.

Unit-III

Introduction to Fuel Cells: Fuel cells as electrochemical engines, history of fuel cell development. generic fuel cell and stack- fuel cell types: alkaline fuel cells, molten carbonate fuel cells, Pem fuel cells, solid oxide fuel cells, phosphoric acid fuel cells, microbial fuel cells, regenerative fuel cells., potential applications, history of fuel cell development.

Learning Outcomes: After completion of this unit the students will be able to

- ***outlin*e** fuel cell types, history and development(L2)
- ***describe*** fuel cell applications in industries.(L2)

Applications: PEM fuel cells used in commercial vehicles like buses, passenger cars and delivery trucks, Solid oxide fuel cells deployed for stationary power generation in industries.

Unit-IV

Fuel Cell Electro Chemistry: electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, tafel equation, exchange currents, current density, power density, potential and thermodynamics of fuel cell, Introduction to direct methanol fuel cell.

Learning Outcomes: After completion of this unit the students will be able to:

- ***apply*** electrode kinetics and polarization curves to analyze fuel cell performance.(L3).
- ***apply*** energy principles to evaluate fuel cell efficiency.(L3)

Applications: Fuel cell performance in electric vehicles through electrode kinetics and efficiency analysis, Direct methanol fuel cells (DMFC) for portable power devices like laptops and mobile chargers.

Unit-V

Fuel Cell System Design, Integration and Management: Balance of plant components, system configuration and sizing, thermal management and water management, control and power management, hydrogen production from renewable sources and storage; safety issues, cost analysis.

Learning Outcomes: After completion of this unit the students will be able to:

- ***apply*** fuel cell system design, focusing on configuration and management.(L3)
- ***assess*** safety, cost and renewable hydrogen integration in fuel cells.(L3)

Applications: Integrated fuel cell systems used in backup power solutions for data centres, Renewable hydrogen-based fuel cell systems applied in off-grid energy supply.

Text Books:

1. Zhang, J. Z., Li, J., Li, Y., Zhao, Y.,John Wiley & Sons, Hydrogen Generation, Storage and Utilization.
2. Barbir,F.,PEMFuelCells:TheoryandPractice,,Elsevier/AcademicPress.
3. Dinçer, I.,Zamfirescu, C Sustainable Hydrogen Production ,Elsevier.
4. Hoogers G , Fuel Cell Technology Hand Book,., CRC Press.

Reference Books:

1. Gupta, R.B ,Hydrogen Fuel :Production, Transport, and Storage,., CRC press.
2. Altalhi,T.A.,Adnan,S. M., Amin, M. A., John Wiley & Sons, Materials for Hydrogen Production, Conversion and Storage.
3. Detlef Stolten, Bernd Emonts, Fuel Cell Science and Engineering – Materials, Processes, Systems and Technology, Wiley-VCH, 1/e.
4. Laminie, J., Dicks, A., John Wiley, Fuel Cell Systems Explained, Wiley.

Web source reference:

1. Fuel Cell Technology, NPTEL Course Link: https://nptel.ac.in/courses/103/102/103102015/)

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

CO	PO1	PO 2	PO 3	PO4	PO 5	PO 6	PO7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	3	3	3	-	-	2	3	-	-	-	-	2	2	1
CO2	3	2	2	1	-	2	3	-	-	-	-	2	2	1
CO3	3	2	1	-	-	2	3	-	-	-	-	2	2	1
CO4	3	3	2	2	2	2	2	-	-	-	2	2	2	1
CO5	3	3	3	2	2	2	3	-	-	-	2	2	2	2
CO*	**3**	**3**	**3**	**1**	**2**	**2**	**3**	**-**	**-**	**-**	**2**	**2**	**2**	**1**

** For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-PE4102.3	**Supply Chain Management (Professional Elective-V)**	3	0	0	3

Course objectives: The objectives of the course are

- Investigate the integration of manufacturing systems and supply chain processes to promote operational efficiency and sustainable development goals.
- Explore innovative approaches and emerging trends in supply chain and logistics management to foster adaptability and lifelong learning.
- Evaluate decision-making frameworks in supply chain management, with practical applications in various industries.
- Able to apply core principles of manufacturing systems, logistics, and supply chain management to diverse, evolving industry contexts.
- Enhance critical thinking and problem-solving skills to make informed, data-driven decisions in sourcing, inventory control, and transportation logistics

Course Outcomes: On successful completion of this course, students will be able to

- ***Explain*** the fundamental concepts and principles of supply chain management and their role in optimize decision-making.(L2)
- ***Identify*** the prospective supplier with Vendor rating and make effective make-or-buy decisions through quantitative analysis. (L3)
- ***Apply*** inventory management concepts for deterministic inventory models to optimize total inventory control costs (L3)
- ***Design*** the inventory management systems for probabilistic inventory models(L4)
- ***Determine*** optimal decisions to manage the Supply Chain to enhance efficiency and sustainability. (L3)

UNIT-I

Introduction to Supply Chain Management (SCM): Characteristics of Manufacturing systems, Concept of Logistics Management, Concept of supply chain management, Core competency, Value chain, supply chain efficiency, Flowin supply chains, Key issues in supply chain management, Forecasting techniques, Production decisions in supply chain management, SWOC analysis, Product life cycle, its relation to supply chain management, Global Trends and Challenges in Supply Chains

Learning Outcomes: At the end of this unit, the student will be able to

- ***compare*** Logistics and Supply Chain Management (L2)
- ***explain*** the key issues in supply chain management (L2)

Application: Automobile plants, Machinery units, Machine tools industry, Electronic goods industry.

UNIT-II

Purchasing policies, Purchasing process, ethics in purchasing, Role of Transportation, Procurement and Transportation – Importance of suppliers, Outsourcing benefits, Supplier selection Evaluating a potential supplier, Vendor rating –Methods, Quantitative Sustainable Procurement and Transportation Practices Make or buy decisions – factors to be considered, Quantitative decisions

Application: Online ordering system, Purchase of capital goods in large scale industries, Selection of supplies in manufacturing plants.

Learning Outcomes: At the end of this unit, the student will be able to

- ***explain*** the sources to get suppliers information.(L2)
- ***apply*** Quantitative methods for transportation decisions (L3)

UNIT-III

Inventory Management –Objectives, functions, Significance of Inventory, types of inventories, Costs associated with inventory control, Deterministic Inventory Models without shortages, exercises, Quantity Discounts model, exercises, Selective Inventory control methods, ABC analysis–procedure, VED analysis

Application: Stores management in manufacturing plants, Pharmacy stores

Learning Outcomes: At the end of this unit, the student will be able to

- ***explain the*** significance of Inventory Management. [L2]
- ***solve*** cost analysis problems to identify and minimize costs associated with inventory control. [L3]

UNIT-IV

Bull whip effect, Information system for Supply Chain Management, Probabilistic Models- Q-system, Probabilistic Models- P- system, Reorder level calculation, buffer stock calculation, and service level -Exercises

Application: Inventory management with uncertainties in manufacturing plants

Learning Outcomes: At the end of this unit, the student will be able to

- ***calculate*** reorder level for inventory system to ensure appropriate inventory levels and service level [L3]
- ***explain*** the bullwhip effect to meet demand in managing the Supply Chain[L2]

UNIT-V

Decision making in Supply Chain Management–Applications of Supply Chain Management Warehouse inventory management system-exercises, simulation tool in Supply Chain Management Product data management–Reverse logistics- need, procedure, green supply chain– Cases in Automobile industry – Machine tools industry, electronic goods

Application: Warehouse management in manufacturing plants, Automobile industry –Machine tools industry, electronic goods industry

Learning Outcomes: At the end of this unit, the student will be able to

- ***develop*** simulation model for Warehouse inventory management[L3]
- ***explain*** the role of reverse logistics for sustainable development[L2]

Text Books

1. Doebler ,D.W. and Burt, D.N., Purchasing and Supply Chain Management: Text and Cases, Sixth Edition, McGraw-Hill Publishing Company Limited, New Delhi.

Reference Books

1. Chopra, S., and Meindl, P., Supply Chain Management: Strategy, Planning and Operations. Second Edition, Pearson Education (Singapore) Pvt. Ltd.
2. Simchi-Levi,D., Kaminsky,P., and Simchi-Levi, E., Designing & Managing the Supply Chain: Concepts, Strategies & Case studies. Second Edition, Tata Mc Graw-Hill Publishing Company Limited, New Delhi.

Web Source References:

1. https://onlinecourses.nptel.ac.in/noc22_mg15
2. https://nptel.ac.in/courses/112107238
3. https://onlinecourses.nptel.ac.in/noc21_mg79
4. https://onlinecourses.nptel.ac.in/noc20_me30
5. https://onlinecourses.swayam2.ac.in/imb21_mg23

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

CO	PO1	PO 2	PO 3	PO4	PO 5	PO 6	PO7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	3	3	3	2	-	1	-	1	-	-	2	3	3	3
CO2	3	3	3	2	1	1	-	2	-	-	2	3	3	3
CO3	3	3	3	2	1	1	-	1	-	-	2	3	3	3
CO4	3	3	3	2	1	1	-	1	-	-	2	3	3	3
CO5	3	3	3	2	1	1	-	1	-	-	2	3	3	3
CO*	3	3	3	2	1	1	-	1	-	-	2	3	3	3

* *For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-PE4102.4	**CNC and Adaptive Control (Professional Elective-V)**	3	0	0	3

Course Objective: The objectives of the course are to

- Explain foundational principles of NC systems, including system classifications, control methods, and component functions in manufacturing.
- Explore the design principles, performance characteristics, and accuracy enhancement methods of NC machine tools in modern manufacturing.
- Develop the ability to create and implement NC part programs for various machining operations
- Develop computer-aided part programs for CNC machining operations using APT language.
- Understand the principles and applications of CNC, DNC, and Adaptive Control systems in manufacturing.

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

- ***Analyse*** different NC system types and control schemes to identify their roles in automated manufacturing. **(L4)**
- ***Understand*** the fundamentals of machining process and different types of cutting tools.**(L2)**
- ***Develop*** NC part programs for machining operations using manual programming techniques **(L3)**
- ***Develop*** the computer-aided part programs for CNC machining operations. **(L3)**
- ***Analyse*** the application of CNC, DNC, and Adaptive Control systems in manufacturing environments to optimize production processes**(L4)**

Unit-I

INTRODUCTION: Basic concepts in manufacturing systems, fundamentals of numerical control, advantages of NC systems, classification of NC systems, point to point and contouring NC systems, incremental and absolute systems, open loop and closed loop systems, encoder, punched tape.

Learning Outcomes: At the end of this unit, the student will be able to:

- ***explain*** the differences between point-to-point and contouring systems, incremental vs. absolute modes, and open vs. closed-loop control. **(L2)**
- ***classify*** NC systems based on motion control, feedback mechanism, and coordinate systems. **(L3)**

Applications: CNC machining, aerospace industry, automotive industry, Mold and die manufacturing, Machine tool control: Automated manufacturing, process control.

Unit-II

FEATURES OF NC MACHINE TOOLS: Fundamentals of machining, design considerations of NC Machine tools, methods of improving machine accuracy, tool deflection and chatter, lead screw, thermal deformations, increasing productivity with NC machines, machining Centres.

Learning Outcomes: At the end of this unit, the student will be able to:

- ***explain*** the fundamentals of machining and their relevance to NC machine tools. ***(L2)***

- ***describe*** the effects of tool deflection, chatter, and thermal deformation on machining accuracy. ***(L2)***
- ***illustrate*** how design features like lead screws and machining centres contribute to NC machine functionality. ***(L2)***

Applications: Diagnostic and Maintenance Strategies, Precision Engineering in CNC Machine Design, Improving Accuracy through Mechanical Components, Design of High-Precision CNC Machines, Productivity Optimization in CNC Workshops

Unit-III
NC PART PROGRAMMING: Introduction, NC coordinate system, Manual part programming, Codes and concepts, types of tape formats, Tool Length and radius compensation, point to point and contour programming examples, canned cycles, Subroutines, MACROS, simple problems of Drilling, Turning and two-dimensional Milling
Learning Outcomes: At the end of this unit, the student will be able to:
- ***explain*** NC coordinate systems and manual part programming concepts **(L2)**
- ***apply*** codes and formats for NC programming, including tool length and radius compensation **(L3)**
- ***develop*** part programs for point-to-point and contour machining operations **(L3)**

Applications: CNC machining, aerospace industry, automotive industry, Mold and die manufacturing.

Unit-IV
COMPUTER AIDED PART PROGRAMMING: advantages of computer aided programming, post processor, APT programming, Geometric statements, motion statements, additional APT statements, simple problems of APT programming.

Learning Outcomes: At the end of this unit, the student will be able to:
- ***explain*** the advantages of computer-aided programming **(L2)**
- ***write*** APT programs using geometric statements, motion statements, and additional APT statements **(L3)**
- ***translate*** post-processors to translate APT code into machine-specific code **(L3)**

Applications: Complex part manufacturing, Increased productivity.

Unit-V
CNC, DNC AND ADAPTIVE CONTROL: Introduction, problems with conventional NC, principles of operation of CNC, features of CNC, advantages of CNC, direct numerical control, types and functions of DNC, advantages of DNC, Adaptive Control machining systems, types, benefits of Adaptive control systems.

Learning Outcomes: At the end of this unit, the student will be able to
- ***explain*** the concept and functions of DNC systems **(L2)**
- ***describe*** the benefits and applications of Adaptive Control systems**(L2)**
- ***compare*** CNC, DNC, and Adaptive Control systems **(L3)**

Applications: Aerospace industry, automotive industry, Mould and die manufacturing, High-precision manufacturing.

Text Books:

1. T.K. Kundra, Numerical Control and Computer Aided Manufacturing, 1st Edition, Tata McGraw-Hill Education.
2. P.N. Rao, CAD/CAM: Principles and Applications, 4th Edition, McGraw-Hill Education.
3. Mikell P. Groover, Automation, Production Systems, and Computer-Integrated Manufacturing, 4th Edition, Pearson Education.

Reference Books:

1. T.K.Kundra, P.N.Rao & N.K.Tewari, Numerical Control & Computer Aided Manufacturing .
2. T.K.Kundra, P.N. Rao & N. K. Tiwari, Computer Aided Manufacturing, (T.M.H)
3. Y. Koren, Computer Control of Manufacturing Systems
4. M.P.Groover & E.W.Zimmers, CAD/CAM, (PHI)
5. M.P.Groover Automation, Production Systems and CIM (P.H.I).
6. PN Rao , "CAD / CAM ", (PHI)

Web Sources References:

1. https://youtu.be/_5r2XR1h1aQ?si=vNipyuAzepcNAWG8
2. https://youtu.be/FNYEXjRmDtI?si=ZbIvMPKMSht57UmD
3. https://youtu.be/_t_8IdR7jkI?si=DRt0HwzeGjt13KEh
4. https://youtu.be/DpDLHvWbY2I?si=7_W6RLoNZf8DgiB5
5. https://youtu.be/0H60K9mhcnY?si=pA8Q0RUVcry6cp2M
6. https://youtu.be/5b8P3flb26I?si=ynZjBTeWPiZw0_w_

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

CO	PO1	PO 2	PO 3	PO4	PO 5	PO 6	PO7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	3	2	2	1	2	-	-	-	1	2	3	2	3	2
CO2	3	3	2	1	2	-	-	-	1	1	2	1	2	1
CO3	3	2	3	3	1	2	-	-	2	3	3	3	3	3
CO4	3	2	3	3	2	2	-	-	2	3	3	3	3	3
CO5	3	2	3	2	2	2	-	-	2	3	3	3	3	3
CO*	**3**	**2**	**3**	**2**	**2**	**2**	**-**	**-**	**2**	**3**	**3**	**3**	**3**	**3**

** For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-PE4102.5	**Artificial Intelligence and Machine Learning in Manufacturing (Professional Elective-V)**	3	0	0	3

Course Objectives: The main objectives of this course are to:

- Introduce the fundamentals of Artificial Intelligence (AI) and its relevance to modern manufacturing systems.
- Enable students to understand and apply AI techniques like Machine Learning, Expert Systems, and Fuzzy Logic in industrial scenarios.
- Familiarize students with AI applications in predictive maintenance, quality control, process optimization, and robotics.
- Develop the ability to analyze manufacturing data using AI-based decision-making tools.
- Encourage innovation in smart manufacturing by integrating AI with Industry 4.0 technologies.

Course Outcomes: After completing this course, the students will be able to:

- ***Explain*** the role and benefits of Artificial Intelligence in modern manufacturing and Industry 4.0. *(L2)*
- ***Apply*** machine learning algorithms to real-world problems like fault detection and predictive maintenance in manufacturing. *(L3)*
- ***Develop*** expert systems to support manufacturing decision-making and diagnostics. *(L5)*
- ***Analyze*** and implement fuzzy logic and neural network models for manufacturing process control. *(L4)*
- ***Evaluate*** advanced AI applications in smart robotics, digital twins, and AI-driven production systems. *(L5)*

UNIT I:

Introduction to AI in Manufacturing:

Definition and scope of AI in engineering, Evolution of AI and its relationship with automation, Traditional automation vs. AI-based decision-making, Role of AI in Industry 4.0 and Smart Factories, Cyber-Physical Systems (CPS) and AI, Benefits and limitations of AI in manufacturing, Case studies: AI in production lines, real-time process control

Learning Outcomes: At the end of this unit, students will be able to:

- ***explain*** the role of AI in Industry 4.0 and smart factories. *(L2)*
- ***identify*** various industrial domains where AI is being effectively applied. *(L1)*
- ***summarize*** the structure and components of cyber-physical systems used in manufacturing. *(L2)*

UNIT II:

Machine Learning for Manufacturing Systems:

Overview of ML algorithms and relevance to manufacturing, Supervised, unsupervised, and reinforcement learning, Classification (SVM, Decision Trees, k-NN) and Regression models, Clustering techniques (K-means, Hierarchical) for pattern detection, Feature engineering and preprocessing of sensor data, Predictive maintenance using historical data, Intro to deep learning: CNN and RNN applications in fault detection, Tools: Python, Scikit-learn, TensorFlow, MATLAB

Learning Outcomes: At the end of this unit, students will be able to:

- ***classify*** different types of machine learning and their relevance in manufacturing systems. *(L4)*
- ***illustrate*** the use of deep learning models in image-based quality inspection. *(L2)*

UNIT III:

Expert Systems and Knowledge Representation

Components of an expert system: knowledge base, inference engine, user interface, Rule-based reasoning and IF-THEN rule chaining, Certainty factors and decision trees, Knowledge acquisition methods: interviews, machine learning, simulations, Semantic networks, ontologies, and frames, AI-based troubleshooting and fault diagnostic systems, Case study: Expert systems in CNC, PLCs, and maintenance management

Learning Outcomes: At the end of this unit, students will be able to:

- ***construct*** rule-based systems using IF-THEN logic for fault diagnosis. *(L3)*
- ***apply*** semantic networks and ontologies in manufacturing problem domains. *(L3)*
- ***analyze*** case studies of expert systems in CNC fault detection and process control. *(L4)*

UNIT IV:

Fuzzy Logic and Neural Networks in Manufacturing : Fundamentals of fuzzy logic and fuzzy inference systems, Designing fuzzy rule-based controllers, Integration of fuzzy logic with PLCs and SCADA, Neural networks: architecture, activation functions, training algorithms, Backpropagation and real-time adaptation, Process optimization using neural networks and fuzzy hybrid models, Applications: welding control, casting defect prediction, tool wear monitoring

Learning Outcomes: At the end of this unit, students will be able to:

- ***apply*** neural networks for pattern recognition and process optimization. *(L3)*
- ***compare*** hybrid models that integrate fuzzy logic and neural networks in smart factories. *(L4)*

UNIT V:

AI Applications in Smart Manufacturing: Intelligent robotics and AI-based path planning, Machine vision systems and defect detection, Digital twins and virtual commissioning, AI in production planning and real-time scheduling, Role of AI in quality assurance and adaptive control, AI in smart inventory management and logistics, Ethical implications and challenges in AI implementation, Case studies: AI in aerospace, automotive, and healthcare manufacturing

Learning Outcomes: At the end of this unit, students will be able to:

- ***evaluate*** the effectiveness of AI in adaptive process control and defect detection. *(L5)*
- ***discuss*** the role of AI in smart supply chain and demand forecasting. *(L2)*

Textbooks:

1. **Russell, Stuart J., and Peter Norvig**, *Artificial Intelligence: A Modern Approach*, Pearson Education.
2. **Dan W. Patterson**, *Introduction to Artificial Intelligence and Expert Systems*, PHI Learning.
3. **M. Gopal**, *Applied Machine Learning*, McGraw-Hill Education.
4. **Ramesh Babu**, *Artificial Intelligence in Mechanical and Industrial Engineering*, SciTech Publications.

Reference Books:

1. **V.S. Janakiraman, K. Sarukesi, P. Gopalakrishnan**, *Foundations of AI and Expert Systems*, Macmillan India.
2. **David Forsyth**, *Applied Machine Learning*, Springer.
3. **Donald A. Waterman**, *A Guide to Expert Systems*, Pearson.
4. **S. N. Sivanandam**, *Principles of Soft Computing*, Wiley India, 2nd Edition.*(covers fuzzy logic and neural networks)*

Online Resources:

1. **Coursera – AI for Everyone (by Andrew Ng)**
   https://www.coursera.org/learn/ai-for-everyone
2. **edX – Artificial Intelligence in Manufacturing** (by RWTH Aachen University)
   https://www.edx.org
3. **MIT OpenCourse Ware – Artificial Intelligence**
   https://ocw.mit.edu
4. **Google AI – Research and Tools**
   https://ai.google

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

CO	**PO1**	**PO 2**	**PO 3**	**PO4**	**PO 5**	**PO 6**	**PO7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PSO 1**	**PSO 2**
CO1	3	1	1	1	2	1	1	1	1	1	–	1	2	2
CO2	3	3	2	2	3	–	–	–	1	–	1	1	2	2
CO3	3	2	3	2	2	1	–	1	1	1	1	1	2	2
CO4	3	3	2	3	3	–	–	–	–	–	1	1	2	2
CO5	2	2	2	2	2	2	2	2	1	1	2	1	2	2
CO*	**3**	**3**	**2**	**2**	**3**	**2**	**2**	**2**	**1**	**1**	**1**	**1**	**2**	**2**

** For Entire Course, PO & PSO Mapping*

Course Code	Course Name	L	T	P	C
R23MEC-SC4101	**Simulation and Engineering Analysis Laboratory**	1	0	2	2

Course Objectives: The main objectives of this course are to:

- Introduction to computational engineering tools for geometry creation, meshing (structured and unstructured), and numerical simulation of engineering problems.
- Develop skills in modeling and analyzing structural systems including trusses, beams, and components under different stress conditions using finite element methods.
- Impart knowledge on fluid flow simulations covering internal and external flows under laminar and turbulent regimes, including incompressible and compressible flows.
- Enable students to perform thermal analysis involving steady-state conduction, forced convection, and natural convection heat transfer in engineering systems.
- Provide exposure to advanced simulation techniques such as Fluid–Structure Interaction (FSI), multiphase flows, and modal/harmonic analysis for real-world engineering applications.

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

- ***Develop*** 2D and 3D geometrical models, generate structured and unstructured meshes, and prepare computational domains for engineering simulations using CAE tools. **(L3)**
- ***Conduct*** structural analysis of trusses, beams, and components to evaluate stresses, deflections, principal stresses, and Von-Mises stresses under various loading conditions. **(L4)**
- ***Perform*** modal and harmonic analysis to determine natural frequencies, mode shapes, and dynamic response characteristics of engineering systems. **(L4)**
- ***Analyse*** fluid flow problems, including internal and external flows under laminar and turbulent conditions, and interpret flow parameters such as velocity, pressure, and turbulence characteristics. **(L4)**
- ***Carry out*** thermal and multiphysics simulations including steady-state heat conduction, forced and natural convection, fluid–structure interaction (FSI), multiphase flows, and compressible flows. **(L4)**

Course Content

Introduction: Illustration of computational engineering analysis, CFD and FEA as engineering analysis tools, review of governing equations of fluid flow, heat transfer and solid mechanics, modelling in engineering, classification of partial differential equations (parabolic, hyperbolic and elliptic), applications of CFD and FEA in Mechanical Engineering, commercial simulation software packages and tools.

Principles of Solution of Governing Equations: Finite Difference Method (FDM), Finite Volume Method (FVM) and Finite Element Method (FEM), discretization of governing equations, convergence, consistency, stability, accuracy and error estimation, boundary and initial conditions, CFD and FEA model formulation.

Mesh Generation and Structural Analysis: Overview of mesh generation, structured and unstr:uctured meshes, mesh quality parameters, mesh refinement and adaptation, finite element modelling of trusses and beams, stress and strain analysis, plane stress, plane strain and axisymmetric analysis, principal stresses, Von-Mises stress criterion, deformation and deflection analysis.

Solution Algorithms and Fluid Flow Analysis: Discretization schemes for pressure, momentum and energy equations, explicit and implicit schemes, first-order upwind, second-order upwind and QUICK schemes, SIMPLE, SIMPLER and MAC algorithms, pressure–velocity coupling algorithms, velocity-stream function approach, numerical solution of Navier–Stokes equations, simulation of incompressible internal and external laminar and turbulent flows.

Thermal and Multiphysics Simulations: Steady-state thermal analysis, conduction and convection heat transfer modelling, forced and natural convection simulations, modal analysis, harmonic response analysis, fluid–structure interaction (FSI), multiphase flow modelling, compressible flow simulations, simulation workflow including geometry creation, mesh generation, material properties, solver settings, convergence monitoring, post-processing and visualization of results.

List of Experiments:

1. 2D and 3D structured grid generation for flat plate and aerofoil models.
2. 3D unstructured grid generation for pipe flow and external aerodynamic problems.
3. Steady-state heat transfer analysis of plane and axisymmetric components.
4. Simulation of incompressible internal laminar and turbulent flows.
5. Simulation of incompressible external laminar and turbulent flows.
6. Numerical analysis of forced convection and natural convection heat transfer.
7. Fluid–Structure Interaction (FSI): Flow past a cylinder and flow over an aerofoil.
8. Simulation of multiphase flows.
9. Simulation of compressible flows.
10. Perform the Structural analysis subjected to Static Load
11. Structural Analysis of a plate with a Circular hole
12. Determine the internal stresses in cylinders

Note:

Any ten experiments have to be completed

Text Books:

1. P.S. Ghosdastidar, Computer Simulation of Flow and Heat Transfer, Tata McGraw- Hill.

2. Muralidhar, K., and Sundararajan,T. Computational Fluid Flow and Heat Transfer, Narosa Publishing. House .

Reference Books:

1. Niyogi, P. Chakrabarty, S.K. and Laha, M.K., Introduction to computational fluid dynamics, Pearson education

2. S K Gupta. Numerical Methods for Engineers, New Age Publishers.
3. Anderson J.D. Computational Fluid Dynamics, Mc-Graw Hills.
4. Numerical Heat Transfer and Fluid Flow: Suhas V. Patankar
5. An introduction of computation fluid dynamics: Versteeg & Malalasekera

COURSE OUTCOMES VS POs MAPPING

[1-*slight* (low), 2 - *moderate* (*medium*) and 3- substantial (high)]

CO	**PO1**	**PO 2**	**PO 3**	**PO4**	**PO 5**	**PO 6**	**PO7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PSO 1**	**PSO 2**
CO1	3	3	2	2	3	-	-	-	2	2	-	3	3	2
CO2	3	3	3	3	3	-	-	-	2	2	-	3	3	2
CO3	3	3	2	3	3	-	-	-	2	2	-	3	3	2
CO4	3	3	2	2	3	-	-	-	2	2	-	3	3	2
CO5	3	3	3	3	3	-	2	-	2	2	-	3	3	2
CO*	**3**	**3**	**3**	**3**	**3**	**-**	**2**	**-**	**2**	**2**	**-**	**3**	**3**	**2**

** For Entire Course, PO & PSO Mapping*

Honours Course Track Offered by the Mechanical Department
Track: Manufacturing Technology

Course Code	Course Name	L	T	P	C
R23MEC-HN4101	**Optimization and Reliability (Honours Course-4)**	**3**	**0**	**0**	**3**

Course Objectives: The objectives of the course are to

- Provide a comprehensive understanding of optimization principles and classical optimization techniques
- Familiarize to solve complex non-linear optimization problems using the advanced techniques.
- Develop a comprehensive understanding of system simulation and its applications in solving complex real-world problems
- Explore the concepts to improve system reliability through design strategies
- Develop reliability improvement and maintenance strategies for enhancing system performance and operational efficiency.

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

- ***Develop*** mathematical models to solve single-variable and multivariable optimization problems for engineering applications (L3)
- ***Analyze*** simulation model of systems for optimal decisions under uncertainties. (L4)
- ***Construct*** mathematical models for goal programming problems non-linear programming problems to address practical issues and make optimal decisions(L3)
- ***Apply*** the reliability engineering principles, probability distributions and system reliability models to find the reliability of mechanical components and engineering systems. (L3)
- ***Analyze*** the reliability of systems using reliability assessment techniques and maintenance strategies and in managing the lifecycle of engineering systems. (L4)

Unit-I

Introduction to Optimization and Classical Optimization Techniques: Basic Concepts and introduction of engineering optimization, Optimization models, mathematical models, sequencing models, decision trees, single-variable optimization, Multivariable optimization with no constraints, equality constraints and inequality constraints. Sensitivity analysis, exercises, merits and demerits of classical optimization techniques. Real world applications.

Applications: Optimization of machining parameters, Optimization of weight for mechanical components, Cost optimization in manufacturing and production processes.

Learning outcomes: At the end of the unit, student will be able to

- ***understand*** classical optimization techniques.(L2)
- ***calculate*** optimal values of functions.(L3)
- ***apply*** fundamental concepts of engineering optimization for solving single-variable and multivariable optimization problems.(L3)

Unit–II

Optimization models under uncertainty: Decision theory, decision trees, sampling concepts in decision making Introduction to System Simulation, Mathematical Modeling of Systems Simulation, Probability and Statistics in Simulation, , Monte Carlo simulation, applications of simulation, merits and demerits of simulation, Simulation languages, Applications and Case Studies

Applications: Decisions in Inventory management, Supply Chain decisions, Design of waiting line models, Production planning in make to order environment

Learning outcomes: At the end of the unit, student will be able to

- ***explain*** the concept of system simulation and its significance.(L2)
- ***illustrate*** procedure for Monte Carlo simulation.(L3)
- ***develop*** simulation model of systems for optimal decisions under uncertainties .(L3)

Unit III

Non Linear Programming: Basic concepts of Non-linear programming, formulation of NLPP, Graphical method. Method of Lagrange multipliers, Kuhn-Tucker conditions. Introduction to quadratic programming, Integer Programming

Goal Programming: concepts of goal programming, Applications of goal programming, Formulation of goal programming problems, solution methods for two variable and three variable problems, sensitivity analysis. Simplex method to solve GPP.

Applications: Preparation of production plan in manufacturing industries with multiple objectives, Product design meeting the customer requirements

Learning outcomes: At the end of the unit, student will be able to

- ***develop*** mathematical models for optimization(L3)
- ***find*** optimal solutions for goal programming problems(L3)
- ***apply*** the relevant conditions for optimizing the non-linear programming problems(L3)

Unit-IV

Reliability Engineering and Quantitative Reliability Analysis:

Product life cycle and reliability concepts, Reliability terminology, Failure mechanisms in mechanical systems, Bathtub curve and hazard rate analysis, Reliability function and cumulative failure distribution, Failure rate models, Probability distributions for reliability analysis. Reliability analysis of engineering systems. Numerical problems on system reliability.

Applications: Reliability of spare parts in workshops, reliability of consumer products

Learning outcomes: After completing this unit, students will be able to:

- ***understand*** the failure rate curve for reliability computations(L2)
- ***apply*** reliability functions, probability distributions, and failure rate models to calculate the reliability of mechanical components and systems. *(L3)*

Unit-V

Reliability Assessment: Quality analysis, Costs, Quality function deployment, Quality tools, Failure Modes and Effects Analysis (FMEA), Root Cause Analysis (RCA),Fault Tree Analysis(FTA). Reliability testing and life testing, Reliability-Centered Maintenance (RCM), Industrial Standards, Methods to improve system reliability, Preventive Maintenance, TPM. Real-world examples and industrial case studies.

Applications: Industrial Safety Engineering, Consumer Product Design

Learning outcomes: After completing this unit, students will be able to:

- ***explain*** the concepts of quality function deployment and reliability analysis for reliable assessment of engineering systems.(L2)
- ***apply*** reliability assessment tools to analyze failures and improve the reliability of engineering systems.(L3)

Text Books

1. S. S. Rao, *Engineering Optimization: Theory and Practice*, John Wiley & Sons.
2. Srinath, L. S., *Reliability Engineering*, Affiliated East-West Press Pvt. Ltd., New Delhi.

References

1. J. S. Arora, *Introduction to Optimum Design*, Academic Press
2. R. Saravanan, *Manufacturing Optimization through Intelligent Techniques*, CRC Press.

CO-PO/PSO Mapping

[1-slight (low), 2- moderate (medium) and 3-substantial (high)]

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

**For Entire Course, PO & PSO Mapping*

Track: Thermal Engineering

Course Code	Course Name	L	T	P	C
R23MEC-HN4102	**Cryogenic Engineering (Honours Course-4)**	**3**	**0**	**0**	**3**

Course objectives: The objectives of the course are to

- Provide knowledge on the evolution of low-temperature science.
- Provide understanding of the properties of materials at low temperatures.
- Familiarize with various gas liquefaction systems.
- Provide insights into the design aspects of cryogenic storage and transfer lines.
- Illustrate the applications of cryogenics in real-life situations.

Course Outcomes: On successful completion of this course, students will be able to

- ***Comprehend*** the material properties at cryogenic temperatures.(L2)
- ***Apply*** liquefaction cycles to determine thermal efficiency. (L3)
- ***Utilize*** appropriate working media and cooling techniques for liquefaction to solve operational challenges in cryogenic systems. (L3)
- ***Explain*** cryogenic storage, insulation and safety systems. (L2)
- ***Comprehend*** the applications of cryogenic systems. (L2)

Unit I:

Fundamentals of Cryogenics: Introduction to cryogenic systems, historical evolution, and significance. Low-temperature properties of engineering materials: mechanical (strength, ductility), thermal (conductivity, specific heat), electrical (resistivity), and magnetic (diamagnetism, superconductivity) behaviours. Properties and applications of cryogenic fluids (liquid nitrogen, oxygen, hydrogen, helium). Emerging applications in space, medicine, and superconductivity.

Learning Outcomes: After completion of this unit, the student will be able to

- ***explain*** fundamental cryogenic concepts and material importance. (L2)
- ***summarize*** material property changes at cryogenic conditions. (L2)

Application Areas: Material selection for cryogenic storage tanks, Safe handling of liquid nitrogen in laboratories and medical facilities, Superconducting magnet design.

Unit II

Liquefaction Systems and Cycles: Thermodynamics of liquefaction: ideal vs. real systems. Joule-Thomson expansion, adiabatic expansion. Liquefaction cycles: Linde-Hampson, Claude, Collins, and cascaded systems. Magnetic cooling, Stirling/Gifford-McMahon (G-M) cryocoolers, and pulse tube refrigerators. Critical components (compressors, heat exchangers) and their roles.

Learning Outcomes: After completion of this unit, the student will be able to

- ***Solve*** thermal efficiency losses in Linde-Hampson or Claude cycles by applying Joule-Thomson and adiabatic expansion principles to compare ideal vs. real liquefaction systems. (L3)

- ***Select*** liquefaction cycles or cryocoolers for a given temperature range based on thermodynamic constraints. (L3)

Application Areas: Industrial gas plants (O_2/N_2 liquefaction using Linde-Hampson cycles), Spacecraft cooling systems (Claude cycle for hydrogen liquefaction), MRI cryostat maintenance (G-M cryocoolers for maintaining liquid helium temps).

Unit III:

Gas Liquefaction and Cryogenic Refrigeration: Production of low temperatures for neon, hydrogen, and helium. Critical components (valves, expanders) in liquefaction systems. Ideal refrigeration systems: liquids/gases (N_2, He) vs. solids (magnetic refrigerants) as working media. Regenerative vs. recuperative cooling techniques.

Learning Outcomes: After completion of this unit, the student will be able to

- ***Describe*** the function of critical components in liquefaction systems. (L2)
- ***Explain*** the principles of various cooling techniques in cryogenic systems. (L2)

Application Areas: Helium liquefaction for particle accelerator superconducting magnets, Magnetic refrigeration systems for ultra-low-temp physics experiments, Hydrogen fuelling stations (on-site liquefaction using recuperative cooling)

Unit IV:

Cryogenic Storage, Insulation, and Safety: Cryogenic storage vessels (Dewars, cryostats) and transfer systems. Insulation types: vacuum, multi-layer, powder, and foam-based. Hazards: thermal contraction, oxygen deficiency, combustion. Safety protocols (ASME/ISO standards) and accident prevention.

Learning Outcomes: After completion of this unit, the student will be able to

- ***Describe*** cryogenic storage and insulation methods. (L2)
- ***Identify*** hazards and safety protocols in cryogenic systems. (L2)

Application Areas: Design of vacuum-insulated Dewars for medical cryogen transport, Safety protocols for LNG storage terminals (combustion/oxygen deficiency risks), Aerospace cryogenic insulation (multi-layer insulation for liquid hydrogen rockets).

Unit V:

Applications of Cryogenic Systems: Space technology (rocket propulsion, satellite cooling). Superconductivity (MRI, maglev trains). Biomedical (cryosurgery, bio-preservation). Industrial (food freezing, metal treatment, in-flight LOX generation).

Learning Outcomes: After completion of this unit, the student will be able to

- ***Identify*** key cryogenic applications in space, superconductivity, and biomedical fields. (L2)
- ***Explain*** the use of cryogenics in industrial processes. (L2)

Application Areas: Space: Cryogenic rocket engines (LOX/LH2 propulsion in SpaceX Starship), Medical: Cryopreservation of biological samples (sperm/embryo banks), Industrial: Food freeze-drying using liquid nitrogen spray, Energy: Superconducting fault current limiters (SFCL) in power grids

Text books

1. Mamata Mukhopadhyay, *Fundamentals of Cryogenic Engineering*, 4th ed., PHI.
2. Randall F. Barron, *Cryogenic Systems*, McGraw-Hill.
3. Thomas Flynn, *Cryogenic Engineering*, Revised & Expanded, CRC.
4. Arora and Domukundwar, *Refrigeration and Air-conditioning*, Dhanpat Roy & Co.
5. R. B. Scott, *Cryogenic Engineering*, 4th ed., Van Nostrand Co.

Reference books

1. A. R. Jha, *Cryogenic Technology and Applications*, Butterworth-Heinemann.
2. Timmerhaus et al., *Cryogenic Engineering: Fifty Years of Progress*, Springer.
3. Klaus D. Timmerhaus& Thomas Flynn, *Cryogenic Process Engineering*, Plenum Press.
4. Herald Weinstock, *Cryogenic Technology*.
5. Robert W. Vance, *Cryogenic Technology*, Wiley.

Web resources:

1. https://archive.nptel.ac.in/courses/112/101/112101004/
2. https://onlinecourses.nptel.ac.in/noc24_me68/preview
3. https://trc.nist.gov/cryogenics/cryocoolers.html
4. https://nanoscience.oxinst.com/resources/video-library

CO-PO/PSO Mapping

[1-slight (low), 2- moderate (medium) and 3-substantial (high)]

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

**For Entire Course, PO & PSO Mapping*

Track: Design Engineering

Course Code	Course Name	L	T	P	C
R23MEC-HN4103	**Design with Advanced Materials (Honours Course-4)**	3	0	0	3

Course Objectives: The objectives of the course are

- Introduce a strong foundation in the behavior and classification of materials.
- Familiarize the criteria for material selection in engineering design based on cost, performance, and environment.
- Understand the properties and applications of modern metallic and non-metallic materials
- Explore the applications and mechanisms of advanced materials such as composites and smart materials.
- Analyze material selection strategies using charts and performance indices.

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

- ***Explain*** the Properties and strengthening mechanisms for engineering materials.(L2)
- ***Select*** the materials considering mechanical properties and cost factors.(L3)
- ***Select*** the modern metallic materials for specific design requirements. (L3)
- ***Find*** the effect of processing methods on the properties of the composite materials.(L3)
- ***Select*** smart and nano materials for the specific engineering applications.(L3)

UNIT I

Fundamentals of Material Science: Elasticity, plastic deformation, dislocations, yield stress, strengthening mechanisms (grain boundary, solid solution), precipitation and dispersion strengthening, Superplasticity, deformation of non-crystalline materials.

Learning Outcomes: After completion of this unit, students will be able to

- ***explain*** the concepts of elasticity and plastic deformation and their relevance to material behavior under mechanical loads.(L2)
- ***understand*** the role of dislocations and yield stress in the initiation and propagation of plastic deformation. (L2)
- ***compare*** different strengthening mechanisms such as grain boundary strengthening, solid solution strengthening, and precipitation hardening. (L2)

Applications: Aerospace Structures, Medical Implants, Automotive Components.

UNIT II

Material Selection and Performance Criteria: Cost and service-based selection, mechanical properties: strength, toughness, fatigue, creep. Ashby's material selection charts and indices.

Learning Outcomes: After completion of this unit, students will be able to

- ***explain*** the Procedure for material selection with Ashby's charts. (L2)
- ***apply*** the specified properties to estimate the material costs. (L3)

Applications: Prosthetics and Medical Implants, Automotive Industry, Aerospace Engineering.

UNIT III

Modern Metallic Materials: Dual phase steels, micro-alloyed steels, HSLA steels, maraging steels, intermetallics (Ni and Ti aluminides), superalloys.

Learning Outcomes:

- ***understand*** the strengthening mechanisms and microstructural features of modern metallic materials that enhance performance under demanding conditions.(L2).
- ***compare*** modern alloys based on mechanical performance, weight, corrosion resistance, and cost for specific applications.(L2)

Applications: Automotive Industry, Aerospace and Jet Engines, Defense and Space.

UNIT IV

Non-Metallic and Composite Materials: Polymeric materials: structure and processing of fibers, foams, adhesives, coatings. Composites: reinforcements, types, properties, processing, and applications.

Learning Outcomes: After completion of this unit, students will be able to

- ***understand*** the structure, properties, and processing methods of various polymeric materials including fibers, foams, adhesives, and coatings.(L2)
- ***explain*** the applications of non metallic and composite materials.(L2)

Applications: Aerospace Industry, Automotive Components, Medical Devices.

UNIT V

Smart and Nano Materials: Shape memory alloys, metallic glasses, quasi-crystals, nanocrystalline materials: structure, behavior, and engineering applications.

Learning Outcomes: After completion of this unit, students will be able to

- ***understand*** the structure and behavior of smart materials.(L2)
- ***compare*** smart and nano materials relate the properties. (L2)

Applications: Electronics and Sensors, Robotics and Actuator, Aerospace and Defense.

Textbooks

1. Thomas H. Courtney – Mechanical Behavior of Materials (2nd Ed., McGraw-Hill)
2. George E. Dieter – Mechanical Metallurgy (McGraw-Hill)
3. M.F. Ashby – Materials Selection in Mechanical Design

References

1. Charles J.A. – Selection and Use of Engineering Materials (3rd Ed., Butterworth Heinemann)

Web Resources:

1. https://nptel.ac.in/courses/113/105/113105106/
2. https://onlinecourses.nptel.ac.in/noc22_mm25/preview
3. https://nptel.ac.in/courses/113/102/113102039/
4. https://nptel.ac.in/courses/112/104/112104221/
5. https://nptel.ac.in/courses/118/102/118102003/

CO-PO-PSO Mapping Table

[1-slight (low), 2- moderate (medium) and 3-substantial (high)]

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

[*] For Entire Course, PO & PSO Mapping

Track: Robotic Engineering

Course Code	Course Name	L	T	P	C
R23MEC-HN4104	**Autonomous Robot System (Honours Course-4)**	3	0	0	3

COURSE OBJECTIVES: The objectives of the course are to:

- Introduce fundamental concepts, classification, and components of robotic systems and end effectors
- Develop understanding of robot kinematics and workspace analysis for industrial applications
- Analyze robot dynamics, force interactions, and actuator behavior in multi-DOF systems
- Impart knowledge on trajectory planning, motion control, and robotic programming
- Provide exposure to autonomous systems, perception, machine learning, and industrial automation technologies

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

- ***Explain*** robot configurations, components, and end effector design principles (L2)
- ***Apply*** kinematic analysis and workspace evaluation of robotic manipulators (L3)
- ***Analyze*** dynamic behavior and force interactions in robotic systems (L4)
- ***Develop*** trajectory planning and motion control strategies for robotic applications (L3)
- ***Implement*** autonomous robotic systems using perception, control, and industrial automation tools (L4)

UNIT – I

Introduction to Robotics: Definition, classification, robot components, degree of freedom, mobile robots, robot characteristics, workspace, specifications, and programming. Applications of robots.
End Effectors: Grippers (pneumatic, hydraulic, magnetic, vacuum), spherical wrist, selection and design considerations, resolution, accuracy, and repeatability.

Learning Outcomes: After completion of this unit, students will be able to

- ***explain*** robot components and classifications (L2)
- ***analyze*** robot performance parameters and workspace (L3)
- ***apply*** friction laws on real life engineering problems. (L3)

Applications: Pick-and-place robots, Assembly automation systems.

UNIT – II

Robot Kinematics: Forward and inverse kinematics, coordinate transformations, workspace analysis, robot motion representation.

Learning Outcomes: After completion of this unit, students will be able to

- ***apply*** kinematic equations for robotic systems (L3)
- ***analyze*** workspace and motion characteristics (L4)

Applications: Robotic arm positioning, Welding and machining robots.

UNIT – III

Robot Dynamics: Lagrangian mechanics, dynamic modeling of multi-DOF robots, static force analysis, transformation of forces and moments.

Learning Outcomes: After completion of this unit, students will be able to

- ***analyze*** dynamic behavior of robotic manipulators (L4)
- ***evaluate*** force interactions and actuator performance (L3**)**

Applications: Force-controlled robots, Heavy payload manipulators

UNIT – IV

Trajectory Planning & Control: Joint space trajectories, path planning, trajectory interpolation, setpoint tracking, actuator dynamics, Cartesian trajectories.

Learning Outcomes: After completion of this unit, students will be able to

- ***develop*** trajectory planning strategies (L3)
- ***apply*** control techniques for robotic motion (L3)

Applications: Autonomous mobile robots, Industrial robotic motion control.

UNIT – V

Autonomous Systems & Perception: Concept of autonomous systems, mission planning, safety and reliability, software and hardware architecture.

Learning Outcomes: After completion of this unit, students will be able to

- ***explain*** autonomous system architecture and perception methods (L2)
- ***apply*** AI and control in autonomous robotic systems (L3)

Applications: Autonomous vehicles and drones, Smart industrial automation systems

Text Books:

1. Hexmoor, Henry – *Essential Principles for Autonomous Robotics*, Springer
2. Yue Yufeng, Wang Danwei – *Collaborative Perception, Localization and Mapping*, Springer.

Reference Books:

1. Cameron Hughes – *Robot Programming*, Que Publishing.
2. MikellGroover – *Automation, Production Systems, and CIM*, Pearson.

COURSE OUTCOMES vs POs MAPPING

(1 – Low, 2 – Moderate, 3 – High)

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PSO 1	PSO 2
CO1	3	2	-	-	1	1	1	2	-	-	-	2	2
CO2	3	3	2	-	1	1	1	2	-	-	-	2	2
CO3	3	2	-	-	1	1	1	2	-	-	-	2	2
CO4	2	2	-	-	1	1	1	2	-	-	-	1	2
CO5	3	3	2	-	1	1	1	2	-	-	-	2	2
CO*	**3**	**2**	**1**	**-**	**1**	**1**	**1**	**2**	**-**	**-**	**-**	**2**	**2**

**For Entire Course, PO & PSO Mapping*