Savitribai Phule Pune University, Pune

Maharashtra, India

Faculty of Science and Technology

National Education Policy (NEP)-2020 Compliant Curriculum

TE - Third Year Engineering (2024 Pattern)

in

Mechanical Engineering

(With effect from Academic Year 2026-27)

Contents

Nomenclature

AEC	Ability Enhancement Courses
AICTE	All India Council for Technical Education
CO	Course Outcome
CEP	Community Engagement Project
CCE	Comprehensive Continuous Evaluation
HSSM	Humanities, Social Science, and Management
MDM	Multidisciplinary Minor
MEC	Mechanical Engineering
MOOC	Massive Open Online Course
NPTEL	National Programme on Technology Enhanced Learning
NEP	National Education Policy
PCC	Program Core Course
PEO	Program Educational Objectives
PSO	Program Specific Objectives
SWAYAM	Study Webs of Active-learning for Young Aspiring Minds
UGC	University Grants Commission
VEC	Value Education Course
VSE	Vocational and Skill Enhancement Course
WK	Knowledge and Attitude Profile

Preface by Board of Studies

Dear Students and Teachers,

We, the members of the Board of Studies – Mechanical Engineering, are very happy to present the Third Year Mechanical Engineering syllabus, effective from the **Academic Year 2026–27 (2024 Pattern).** We are confident that you will find this syllabus both interesting and challenging. The present curriculum will be implemented for Third Year Engineering from the academic year 2026–27, and it will be subsequently extended to the Final Years in the academic years **2027–28**.

Mechanical Engineering is one of the most sought-after branches among engineering students, which necessitates continuous revision and up gradation of the syllabus. Mechanical Engineering is a dynamic discipline that integrates principles from core engineering fields and supports innovation across manufacturing, design, energy, materials, and automation. This curriculum is designed to provide students with a comprehensive understanding of the fundamentals, emerging technologies, and practical applications in Mechanical Engineering, while also equipping them to meet the demands of a rapidly evolving industry.

The revised syllabus aligns with the vision of **NEP-2020**, and conforms to the frameworks set by Savitribai Phule Pune University, AICTE New Delhi, UGC, and various accreditation agencies. It takes into account recent technological developments, innovations, and industry needs to ensure students are well- prepared for professional challenges.

Wherever applicable, additional learning resources such as NPTEL and SWAYAM links are provided at the end of each course. Students are encouraged to utilize these platforms for self-learning, engage in online courses, and undertake additional projects to enhance their knowledge and skill set. On successful completion, they are advised to submit their course certifications, which will further support and enrich their academic growth.

This curriculum is the result of collaborative efforts involving academic experts, industry professionals, and alumni to ensure relevance and excellence. It is designed not only to meet current industry expectations but also to prepare students for higher studies, research, and entrepreneurial ventures in the field of Mechanical Engineering.

We hope this curriculum inspires students to become technically competent professionals, responsible citizens, and contributors to the technological and sustainable advancement of society.

Dr. Pradeep A. Patil
Chairman
Board of Studies - Mechanical Engineering

Program Specific Outcomes

PSO1 : **SPECIFY, DESIGN** and **EVALUATE** mechanical components and systems using modelling and analysis software.

PSO2 : **APPLY** knowledge of machines, tools, automation, properties of advanced materials and modern management methods for manufacturing of mechanical components and systems.

PSO3 : **APPLY** core aspects of thermal and fluid engineering to determine the performance of mechanical systems including power absorbing and power generating systems.

Program Educational Objectives

Program Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the program is preparing a graduate to achieve.

PEO1 : The graduate will have a successful career in mechanical engineering with strong technical, research & professional skills.

PEO2 : The graduate will possess an ability to work in diversified fields along with team work and leadership qualities.

PEO3 : The graduate will continue to learn and to adapt in a society of constantly evolving technological environment

Program Outcomes

Program Outcomes (POs) are statements that articulate what students are expected to know, understand, and be able to do by the time they graduate from the program. These outcomes are aligned with the overall educational objectives of the program and reflect the skills, knowledge, attitudes, and behaviors acquired by students throughout their academic journey. On successful completion of B.E. in Mechanical Engineering, graduating students/graduates will be able to:

PO No.	Title	Program Outcome Description
PO1	Engineering Knowledge	Apply knowledge of mathematics, natural science, computing, engineering fundamentals and an engineering specialization as specified in WK1 to WK4 respectively to develop the solution of complex engineering problems.
PO2	Problem Analysis	Identify, formulate, review research literature and analyze complex engineering problems reaching substantiated conclusions with consideration for sustainable development. (WK1 to WK4)
PO3	Design / Development of Solutions	Design creative solutions for complex engineering problems and design/develop systems/components/processes to meet identified needs with consideration for public health and safety, whole-life cost, net zero carbon, culture, society and environment. (WK5)
PO4	Conduct Investigations of Complex Problems	Conduct investigations of complex engineering problems using research-based knowledge including design of experiments, modelling, analysis & interpretation of data to provide valid conclusions. (WK8)
PO5	Engineering Tool Usage	Create, select and apply appropriate techniques, resources and modern engineering & IT tools, including prediction and modelling, recognizing their limitations to solve complex engineering problems. (WK2 and WK6)
PO6	The Engineer and The World	Analyze and evaluate societal and environmental aspects while solving complex engineering problems for its impact on sustainability with reference to economy, health, safety, legal framework, culture and environment. (WK1, WK5, and WK7)
PO7	Ethics	Apply ethical principles and commit to professional ethics, human values, diversity and inclusion; adhere to national & international laws. (WK9)
PO8	Individual and Collaborative Team Work	Function effectively as an individual, and as a member or leader in diverse/multi-disciplinary teams.
PO9	Communication	Communicate effectively and inclusively within the engineering community and society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations considering cultural, language, and learning differences.
PO10	Project Management and Finance	Apply knowledge and understanding of engineering management principles and economic decision-making and apply these to one's own work, as a member and leader in a team, and to manage projects in multidisciplinary environments.
PO11	Life-Long Learning	Recognize the need for, and have the preparation and ability for: (i) independent and life-long learning, (ii) adaptability to new and emerging technologies, and (iii) critical thinking in the broadest context of technological change. (WK8)

Knowledge and Attitude Profile (WK)

WK No.	Focus Area	Description
WK1	Natural Sciences and Social Sciences	A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences.
WK2	Mathematics and Data Analysis	Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.
WK3	Engineering Fundamentals	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.
WK4	Engineering Specialist Knowledge	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.
WK5	Engineering Design and Environmental Considerations	Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.
WK6	Engineering Practice (Technology)	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.
WK7	Role of Engineering in Society	Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.
WK8	Research and Critical Thinking	Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.
WK9	Ethics and Inclusive Behavior	Ethics, inclusive behavior and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability, etc., with mutual respect.

Reference: Self-Assessment Report (SAR) Format Undergraduate Engineering Programs Graduate Attributes and Professional Competencies Version 4.0 (GAPC V4.0) - (August 2024) Page 55-56

General Rules and Guidelines

Term	Definition
Course Outcomes (COs)	Course Outcomes are narrower statements that describe what students are expected to know and be able to do at the end of each course. These relate to the skills, knowledge, and behavior that students acquire throughout the course.
Assessment	Assessment is one or more processes, carried out by the institution, that identify, collect, and prepare data to evaluate the achievement of **Program Educational Objectives (PEOs)** and **Program Outcomes (POs)**.
Evaluation	Evaluation is one or more processes, performed by the **Evaluation Team**, to interpret the data and evidence gathered through assessment practices. It determines how well PEOs or POs are being achieved, and informs decisions for improvement.

Assessment and Evaluation:

Assessment and Evaluation shall be conducted in two parts: 1. Comprehensive Continuous Evaluation (CCE) 2. End-Semester Examination (ESE)		
Component	**Description**	**Marks**
Comprehensive Continuous Evaluation (CCE)	Conducted at institute level, covering all Units of the syllabus. The design and mark allocation follow the Continuous Assessment Sheet structure.	30
End-Semester Examination (ESE)	Conducted at university level, typically covering the entire syllabus through summative examination.	70
	Total Marks per Subject	**100**

A) <u>Comprehensive Continuous Evaluation (CCE) :</u>

CCE to be conducted either on the basis of Mode 1 or Mode 2.

➢ CCE MODE 1:

To design a Comprehensive Continuous Evaluation (CCE) scheme for a theory subject of 15 or 30 marks with the specified parameters, the allocation of marks and the structure can be as per continuous assessment sheet;

Savitribai Phule Pune University

Board of Studies (Mechanical and Automobile Engineering)

Comprehensive Continous Evaluation (CCE) 30 Marks Distribution

Class: TE-Mechanical Engineering — Subject: Refrigeration and Air conditioning

Exam Seat No.	Roll No.	Name of Student	Unit 1		Unit 2		Unit 3		Unit 4		Unit 5		Cumulative Sum				30 Marks Distribution				Marks obtained out
			Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Internal Test	Attendance	Field Activity	Quiz	Internal Test	Attendance	
			A	B	C	D	E	F	G	H	I	J	SUM(A+C+E+G+I)	SUM(B+D+F+H+J)			P	Q	R	S	SUM(P:Q)
			10	10	10	10	10	10	10	10	10	10	50	50	100	100	15	5	5	5	30
T9028246474	2016	MAAN PANCHAL	8	8	8	8	8	8	8	8	8	8	40	40	60	75	12	4	3	3.8	22.75

Comprehensive Continous Evaluation (CCE) 15 Marks Distribution

Exam Seat No.	Roll No.	Name of Student	Unit 1		Unit 2		Unit 3		Unit 4				Cumulative Sum				15 Marks Distribution				Marks obtained out
			Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz	Field Activity	Quiz			Field Activity	Quiz	Internal Test		Field Activity	Quiz	Internal Test		
			A	B	C	D	E	F	G	H			SUM(A+C+E+G	SUM(B+D+F+H			P	Q	R	S	SUM(P:Q)
			10	10	10	10	10	10	10	10			40	40	100		5	5	5		15
T9970160753	2020	AMOGH SHINDE	8	8	8	8	8	8	8	8			32	32	60		4	4	3		11

Figure 1 Template Comprehensive Continuous Evaluation (CCE) ***Click*** *here to download .*

Field Activities / Home Assignments

Field activities and home assignments are essential components of experiential learning. Under this head, course projects, industrial visits, and guest lectures are to be incorporated. For each unit, one such activity should be designed and executed to reinforce theoretical learning through practical exposure.

1. **Course Projects**

   Course Projects should be framed based on real-world problems relevant to the subject. Each course project must be communicated through one of the following modes. It is recommended to complete all the communication modes across different course projects:

- **Poster Presentation**
- **PowerPoint Presentation**
- **Model Making**
- **Field or Survey Report with Oral Presentation** (e.g., case study)
- **Submission of Digital Content (e.g. Video Summary)**

To evaluate these field activities, **assessment rubrics** should be designed. The rubrics should include criteria such as clarity, innovation, subject relevance, presentation skills, and technical content.

Note: Part of work of any co-curricular activities (relevant to subject contents) like national level project competitions, club activities, paper presentations, startup activities can be accepted as a course projects.

2. **Industrial Visit**

   An industrial visit should be planned in alignment with the subject's scope and should particularly address advancements in the respective field. The purpose is to provide students exposure to actual engineering practices and systems.

Assessment of industrial visits should be carried out using any of the following tools:

- Quiz (based on the visit)
- Interactive video or oral discussion
- Submission of a detailed visit report

3. **Guest Lectures**

   Guest lectures should be relevant to the course and highlight advanced topics or recent trends in the field. Subject experts from academia or industry may be invited.

Assessment methods for guest lectures may include:

- Quiz conducted post-lecture
- Attendance monitoring
- Evaluation of attentiveness and participation

Rubrics can be developed, if possible, to objectively assess student involvement in guest lectures.

4. **Quiz**

   Unit-wise quizzes should be planned and can be conducted either **online** (via LMS, Google Forms) or

offline. Each quiz should include a **pool of 20 questions**, from which **students are required to attempt any 10**. The quizzes should be diversified across the following question types:

- Simple Multiple Choice Questions (MCQs)
- Numerical MCQs
- Image-based Questions
- Match the Following
- Fill in the Blanks
- Drag and Drop (using images or words)

This variety ensures the assessment caters to different cognitive skills and learning styles.

5. Internal Tests

Two major internal tests should be conducted as follows:

1. **Midterm Examination**: This should cover **Unit I and Unit II**, and should include questions targeting **Bloom's Taxonomy Levels 2, 3, and 4** (UNDERSTAND, APPLY, and ANALYZE).
2. **End term Examination**: This should cover the **remaining units** and should also include questions mapped to **BL Levels 2, 3, and 4**.

➢ CCE MODE 2:

Comprehensive Continuous Evaluation scheme in this mode for a theory subject of 30 marks with the specified parameters, the allocation of marks and the structure can be detailed as follows:

Sr. No.	Parameters	Marks	Coverage of Units
1	Unit Test	12 Marks	Unit 1 & Unit 2 (6 Marks/Unit)
2	Assignments/Case Study	12 Marks	Unit 3 & Unit 4 (6 Marks/Unit)
3	Seminar Presentation/ Open Book Test/ Quiz	06 Marks	Unit 5

6. CCE of 15 marks based on all the Units of course syllabus to be scheduled and conducted at institute level. To design a CCE scheme for a theory subject of 15 marks with the specified parameters, the allocation of marks and the structure can be detailed as follows:

Sr. No.	Parameters	Marks	Coverage of Units
1	Unit Test	10 Marks	Unit 1 & Unit 2 (5 Marks/Unit)
2	Seminar Presentation/ Open Book Test/ Assignments/ Case Studies	05 Marks	Unit 3 & Unit 4

- **Unit Test–**

  Format: Questions designed as per Bloom's Taxonomy guidelines to assess various cognitive levels

(Remember, Understand, Apply, Analyze, Evaluate, and Create).

Implementation: Schedule the test after completing Units 1 and 2. Ensure the question paper is balanced and covers key concepts and applications.

- **Sample Question Distribution**–
  1. Remembering (2 Marks): Define key terms related to [Topic from Units 1 and 2].
  2. Understanding (2 Marks): Explain the principle of [Concept] in [Context].
  3. Applying (2 Marks): Demonstrate how [Concept] can be used in [Scenario]
  4. Analyzing (3 Marks): Compare & contrast [Two related concepts] from Units 1 and 2
  5. Evaluating (3 Marks): Evaluate the effectiveness of [Theory/Model] in [Situation].

- **Assignments / Case Study:** Students should submit one assignment or one Case Study Report based on Unit 3 and one assignment or one Case Study Report based on Unit 4.

  – ***Format*:** Problem-solving tasks, theoretical questions, practical exercises, or case studies that require in-depth analysis and application of concepts.

  – ***Implementation:*** Distribute the assignments or case study after covering Units 3 and 4. Provide clear guidelines and a rubric for evaluation.

- **Seminar Presentation: –**

  Format: Oral presentation on a topic from Unit 5, followed by a Q&A session. –

  Deliverables: Presentation slides, a summary report in 2 to 3 pages, and performance during the presentation

  Implementation: Schedule the seminar presentations towards the end of the course. Provide students with ample time to prepare and offer guidance on presentation skills.

- **Open Book Test: –**

  Format: Analytical and application-based questions to assess depth of understanding. – **Implementation**: Schedule the open book test towards the end of the course, ensuring it covers critical aspects of Unit 5

- **Quiz:** –

  Format: Quizzes can help your students practice existing knowledge while stimulating in terest in learning about new topic in that course. You can set your quizzes to be completed individually or in small groups.

  Implementation: Online tools and software can be used create quiz. Each quiz is made up of a variety of question types including multiple choice, missing words, true or false etc

- **Example Timeline for conducting CCE: –**
  1. Weeks 1-4 : Cover Units 1 and 2
  2. Week 5 : Conduct Unit Test (12 marks)
  3. Weeks 6-8 : Cover Units 3 and 4

4. Week 9 : Distribute and collect Assignments / Case Study (12 marks)
5. Weeks 10-12 : Cover Unit 5
6. Week 13 : Conduct Seminar Presentations or Open Book Test or Quiz (6 marks)

- **Evaluation and Feedback: –**
  1. Unit Test: Evaluate promptly and provide constructive feedback on strengths and areas for improvement.
  2. Assignments / Case Study: Assess the quality of submissions based on the provided rubric. Offer feedback to help students understand their performance.
  3. Seminar Presentation: Evaluate based on content, delivery, and engagement during the Q&A session. Provide feedback on presentation skills and comprehension of the topic.
  4. Open Book Test: Evaluate based on the depth of analysis and application of concepts. Provide feedback on critical thinking and problem-solving skills.

B) End-Semester Examination (ESE)

Detailed Scheme for 70 Marks: Unit-Wise Allocation (14 Marks per Unit): Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to Bloom's Taxonomy guidelines for cognitive skills evaluation.

Detailed Scheme for 35 Marks: Unit-Wise Allocation (08 Marks for Unit 1 , 09 Marks for Unit 2, Unit 3 and Unit 4) : Each unit will have a combination of questions designed to assess different cognitive levels. By following this scheme, you can ensure a comprehensive and fair assessment of students' understanding and application of the course material, adhering to Bloom's Taxonomy guidelines for cognitive skills evaluation The following structure is to be followed for designing an ESE for a **theory subject of 70 marks** covering **all 5 units** of the syllabus, with **questions set as per Bloom's Taxonomy** guidelines and **14 marks allocated per unit**.

2. Balanced Coverage

Ensure balanced coverage of all units with questions that assess different **cognitive levels of Bloom's Taxonomy**:

a) **Remembering**: Basic recall of facts and concepts.
b) **Understanding**: Explanation of ideas or concepts.
c) **Applying**: Use of information in new situations.
d) **Analyzing**: Drawing connections among ideas.
e) **Evaluating**: Justifying a decision or course of action.
f) **Creating**: Producing new or original work (if applicable).

Curriculum Structure - Semester V

NEP 2020 Compliant Curriculum Structure

Savitribai Phule Pune University Board of Studies - Mechanical and Automobile Engineering Undergraduate Program – Third Year Mechanical Engineering (2024 pattern)																
Course Code	Course Type	Course Name	Teaching Scheme (Hrs./week)			Examination Scheme and Marks						Credits				
			L	T	P	*CCE	ESE	TW	OR	PR	TOTAL	L	T	P	TOTAL
Semester –V																
PCC301-MEC	Major Course	Heat & Mass Transfer	4			30	70				100	4			4
PCC302-MEC	Major Course	Theory of Machines	3			30	70				100	3			3
PCC303-MEC	Major Course	Design of Machine Elements	4			30	70				100	4			4
PCC304-MEC	Major Course	Manufacturing Process-II	3			30	70				100	3			3
PCC305-MEC	Major Course	Metrology and Quality Control	3			30	70				100	3			3
PCC306-MEC	Major Course	Industrial Fluid Power Lab			2					50	50			1	1
MDM321-MEC	Multidisciplinary Course	Industrial Robotics			2					50	50			1	1
MDM 322-MEC	Multidisciplinary Course	Smart Mechatronics Systems			2					50	50			1	1
	Open Elective	OE is to be chosen compulsorily from faculty other than that of the Major Discipline.	2			15	35				50	2		0	2
Total			**19**	**0**	**06**	**165**	**385**	**0**	**0**	**150**	**700**	**19**	**0**	**3**	**22**

***CCE: Comprehensive Continuous Evaluation**

Important Note: Min.1 to Max.2 hrs. per batch of (20-25 students) to be assigned for ***CCE** and to be considered in teaching load of concerned faculty. (Only applicable for Mode -1)

Curriculum Structure - Semester VI

NEP 2020 Compliant Curriculum Structure

Savitribai Phule Pune University Board of Studies - Mechanical and Automobile Engineering Undergraduate Program – Third Year Mechanical Engineering (2024 pattern)															
Course Code	Course Type	Course Name	Teaching Scheme (Hrs./week)			Examination Scheme and Marks						Credits			
			L	T	P	CCE	ESE	TW	OR	PR	TOTAL	L	T	P	TOTAL
Semester -VI															
PCC351-MEC	Major Course	Computer Integrated Manufacturing	4			30	70				100	4			4
PCC352-MEC	Major Course	Refrigeration & Air-conditioning	3			30	70				100	3			3
PCC353-MEC	Major Course	Transmission System Design	4			30	70				100	4			4
PCC354MEC	Major Course	Thermal and Fluid Engineering Lab-II			4					50	50			2	2
PEC 361-MEC	Program Elective -I	Students can pick the elective from basket	3			30	70				100	3			3
PEC 362-MEC	Program Elective -II	Students can pick the elective from basket	3			30	70				100	3			3
MDM 371-MEC	Multidisciplinary Course	Digital Manufacturing Laboratory			2					50	50			1	1
MDM 372-MEC	Multidisciplinary Course	Engineering Simulation and Analysis			2					50	50			1	1
VSE 381	Vocational Skill Course	Solar Technology and Maintenance			2	50					50	1		1	1
		Total	**17**	**0**	**10**	**200**	**350**	**0**	**0**	**150**	**700**	**18**	**0**	**5**	**22**

Program Elective-I		Program Elective-II	
PEC 361A-MEC	Industrial Tribology	**PEC 362A-MEC**	Product Design and Development
PEC 361B-MEC	Design of Heat Transfer Equipment’s	**PEC 362B-MEC**	Smart Thermal Engineering systems
PEC 361C-MEC	Hydraulic and Pneumatics	**PEC 362C-MEC**	Compressible flow
PEC 361D-MEC	Industrial Engineering	**PEC 362D-MEC**	Advanced Machining Processes

***CCE: Comprehensive Continuous Evaluation**

Note: Students can opt for Open Electives offered by different faculties such as Arts, Science, Commerce, Management, Humanities, or Inter-Disciplinary Studies.

Savitribai Phule Pune University, Pune

Maharashtra, India

TE - Mechanical Engineering (2024 Pattern)

Semester - V Courses

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PCC301-MEC: Heat & Mass Transfer

Teaching Scheme		Credit	Examination Scheme	
Theory	4 Hours/Week	4	CCE	30 Marks
Practical	NA		End-Semester	70 Marks

Prerequisite Courses, if any:

- Fluid Mechanics, Engineering Thermodynamics, Engineering Mathematics

Course Objectives:

1. To INTRODUCE the fundamental mechanisms of heat transfer: conduction, convection, and radiation.
2. To STUDY heat conduction with heat generation, fins, thermal insulation, and transient heat transfer.
3. To APPLY heat transfer principles in real engineering applications including energy systems, manufacturing, and process industries.
4. To PROVIDE knowledge to analyze radiation heat transfer with and without radiation shields.
5. To EVALUATE heat transfer equipment such as heat exchangers used in thermal systems.

Course Outcomes:

After successful completion of the course, students will be able to:

CO1: EXPLAIN fundamental heat transfer mechanisms and analyze heat conduction in engineering systems.
CO2: ANALYZE fins, insulation systems, and transient heat conduction problems.
CO3: APPLY convection heat transfer principles and empirical correlations to determine heat transfer rates.
CO4: ANALYZE radiation heat exchange between surfaces and thermal systems.
CO5: EVALUATE the performance of heat exchangers using LMTD and NTU methods.CO5.

Course Contents

Unit I	Introduction and Conduction (Steady State)	(08 Hours)

Introduction and basic concepts: Introduction, Application areas of heat transfer. Basic modes of Heat Transfer, mechanisms and governing laws for these modes. Concept of 1D, 2D and 3D heat transfer. General three dimensional heat conduction equation in Cartesian coordinates (with derivation), cylindrical and spherical coordinates (no derivation). Thermal Conductivity, variable thermal conductivity, thermal diffusivity. (Simple numerical on modes and laws of transfer of heat transfer)

One dimensional steady state heat conduction: One dimensional steady state heat conduction equation for the plane wall, cylinder and sphere, Overall heat transfer coefficient. Electrical Analogy - thermal resistance of composite structures and thermal contact resistance. Conduction with internal heat generation for plane wall, solid cylinder and solid sphere (Numerical on electrical analogy.)

Real World Assignment

1. Identify the applications of modes of heat transfer and draw the schematics of the same.
2. Draw the thermal resistance circuit of any thermal system or heat transfer equipment and analyze the heat transfer mechanism.
3. Analyze heat transfer through a real composite wall and apply thermal resistance concept.
4. Identify and analyze 1D, 2D, and 3D heat flow in a practical system.

Exemplar / Practical Applications

Industrial case , Copper, aluminum, steel, and insulation materials , Thermal Contact Resistance in Mechanical Assemblies, Industrial system diagrams (furnace wall, pipe insulation, electronic cooling), Simple electrical circuit (resistors, power supply), Machine learning/Numerical Analysis to predict Heat

Flow/heat flux

Unit II	Finned Surfaces, Thermal Insulation and Transient Heat Conduction.	(08 Hours)

Finned surfaces: Extended surface, types of fins, analysis of fins of uniform cross section area for temperature distribution and heat transfer rate for infinitely long & adequately long (with insulated end) fins. Fin efficiency & effectiveness. (Numerical on extended surfaces.)

Thermal insulation and transient heat conduction: Thermal Insulation-types and selection, Critical radius of Insulation for cylinder and sphere, Unsteady state heat transfer, lumped heat capacity analysis, Heisler's charts. Biot's Number, Fourier's Number & their significance. (Numerical on critical radius and lumped heat capacity.)

Real World Assignments

1. Analysis of heat transfer enhancement through fin for any motor/engine/compressor etc.
2. Identify and analyze the thermal insulation systems.
3. Analyse the transient cooling or heating practically using lumped method
4. Analyse the transient cooling or heating practically using Heisler's charts
5. Optimization of Pipe Insulation Using Critical Radius in Steam Power Plants/Electrical Wires.

Exemplar / Practical Applications

Boiler walls, steam pipes, heat exchangers, car radiators, CPU heat sinks, Nuclear fuel rods, engine components, Metal quenching, food cooling, annealing processes, Quenching of metal rods, food freezing, Steam pipes, Electrical wires, Industrial piping systems.

Unit III	Convective Heat Transfer, Mass Transfer	(08 Hours)

Basic concept of convection and forced convection: Concept of hydrodynamics & thermal boundary layer thickness, local and average heat transfer coefficient. Reynolds number, Prandtl number, Nusselt number. Empirical co-relations for external, internal flows, laminar & turbulent flow through conduits. (Numerical on forced convection with given empirical co-relations).

Free or natural convection, **boiling and condensation:** Grashof's number, Rayleigh number, flow over horizontal and vertical plate, Empirical co-relations for cylinders and sphere. **Introduction to mass transfer:** Introduction to mass transfer, diffusion using Fick's Law of Diffusion, and basic applications. (Numerical on natural convection with given empirical co-relations).

Real World Assignment

1. Determine forced convective HTC in pipe flow
2. Determine natural convection HTC on flat plate.
3. Identify and analyze practical applications of free convection
4. Identify and analyze practical applications of force convection

Exemplar / Practical Applications

Steam pipes, electrical wires, industrial piping systems

Unit IV	Radiation Heat Transfer	(06 Hours)

Basic Concepts of Radiation: Radiation, spectrum of radiation, black body radiation, radiation intensity,

Laws of radiation-Kirchhoff, Planck's, Wien's displacement law, Stefan Boltzmann & Lamberts Co-sine law. Emissivity, absorptivity, transmissivity, reflectivity, radiosity, emissive power, irradiation. (Simple numerical on basic radiation).

Radiation heat exchange: Radiation heat exchange between surfaces, shape factor & its laws, radiation between parallel plates, cylinder & spheres. Radiation shields. (Numerical on Radiation shields).

Real World Assignment

1. Study of Radiation & Spectrum (Basic Observation)
2. Determine emissivity of black and grey surface
3. Identify and analyze practical radiation heat transfer systems
4. Analyze radiation shield concept practically

Exemplar / Practical Applications

1. Sun, Rainbow, Furnace, Sunlight, Thermal equilibrium, Spectroscopy, Stars, Solar energy, Illumination, Surface, Coating, Glass, Mirror, Surface radiation, Heater, Solar flux, Buildings, Geometry, Furnace walls, Pipes, Satellites, Thermos flask. element beneath a ceramic glass surface.

Unit V	Heat Exchangers, Boiling and Condensation	(07 Hours)

Introduction & LMTD Method: Introduction and detailed classification of heat exchangers. Overall heat transfer coefficient, fouling factor and its effect on heat exchanger performance. Log Mean Temperature Difference (LMTD) method for heat exchanger analysis. (Numerical on LMTD Method). Effectiveness–**NTU method:** Effectiveness–NTU method for heat exchanger performance evaluation. Boiling and Condensation heat transfer: Pool boiling curve and regimes of pool boiling, Critical heat flux, film and drop wise condensation. (Numerical on Effectiveness-NTU Method).

Real World Assignment

1.Identify and classify heat exchangers used in real systems.

2.Evaluate performance of any heat exchanger using LMTD or NTU approach

3.Study and analyze the effect of deposits on performance of heat exchanger.

4. Identify and photograph dropwise and filmwise condensation process.

Exemplar / Practical Applications

Sun, Rainbow, Furnace, Sunlight, Thermal equilibrium, Spectroscopy, Stars, Solar energy, Illumination, Surface, Coating, Glass, Mirror, Surface radiation, Heater, Solar flux, Buildings, Geometry, Furnace walls, Pipes, Satellites, Thermos flask. element beneath a ceramic glass surface.

Learning Resources

Text Books:

1. P.K. Nag, Heat & Mass Transfer, McGraw Hill Education Private Limited.
2. M.M. Rathod, Engineering Heat and Mass Transfer, Third Edition, Laxmi Publications, New Delhi
3. V. M. Domkundwar, Heat Transfer, Dhanpat Rai & Co Ltd.
4. S.P. Sukhatme, A Textbook on Heat Transfer, Universities Press.
5. R.C. Sachdeva, Fundamentals of Engineering Heat and Mass Transfer, New Age Science.
6. Joshi's Process Equipment Design, by V.V. Mahajani , S.B. Umarji ,Trinity Press
7. S. P. Venkatesan, Heat Transfer, Ane Books Pvt. Ltd.

Reference Books:

1. Franck P. Incropera, David P. DeWitt – Fundamentals of Heat and Mass Transfer,
2. Y. A. Cengel and A.J. Ghajar, Heat and Mass Transfer – Fundamentals and Applications, Tata McGraw Hill Education Private Limited.
3. A.F. Mills, Basic Heat and Mass Transfer, Pearson.
4. Holman, Fundamentals of Heat and Mass Transfer, McGraw – Hill publication.
5. M. Thirumaleshwar, Fundamentals of Heat and Mass Transfer, Pearson Education India.
6. B.K. Dutta, Heat Transfer-Principles and Applications, PHI.
7. C.P. Kothandaraman, S. V. Subramanyam, Heat and Mass Transfer Data Book, New Academic Science.
8. Process heat Transfer, D. Q. Kern, Wiley Publication

MOOC / NPTEL/ YouTube Links: -

https://nptel.ac.in/courses/112101097

https://nptel.ac.in/courses/112106315

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PCC302-MEC: Theory of Machines

Teaching Scheme		Credit	Examination Scheme	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End-Semester**	**70 Marks**

Prerequisite Courses, if any:

- Engineering Mathematics - I and II, Engineering Physics, Engineering Mechanics, Geometric Modelling & Drafting

Course Objectives:

1. To DEVELOP an understanding of kinematic principles of mechanisms and their application in real-life engineering systems.
2. To ANALYZE displacement, velocity, and acceleration of mechanisms using analytical and graphical methods.
3. To SYNTHESIZE mechanisms for desired motion, path, and function generation using appropriate techniques.
4. To APPLY principles of gear kinematics for the analysis of power transmission systems.
5. To DESIGN cam profiles for specified follower motions in industrial applications.

Course Outcomes:

After successful completion of the course, learner will be able to:

CO1. APPLY kinematic concepts to analyze mechanisms used in engineering applications

CO2. ANALYZE displacement, velocity, and acceleration of mechanisms using analytical and graphical methods.

CO3. DESIGN and SYNTHESIZE mechanisms for specified motion and path generation problems.

CO4. ANALYZE gear systems and APPLY kinematic principles in power transmission applications.

CO5. DESIGN cam profiles for required follower motion considering practical constraints

Course Contents

Unit I	Fundamentals of Mechanism	(07 Hours)

Introduction: kinematic link, kinematic pair, kinematic chain, types of constrained motions, types of joints, mechanism, machine, Degree of freedom and Mobility.

Inversions of Mechanisms: Four-Bar Chain, Slider crank Chain, Double slider crank Chain.

Mechanisms with Higher pairs: Equivalent Linkages and their Cases (Sliding Pairs in Place of Turning Pairs, Spring in Place of Turning Pairs, Cam Pair in Place of Turning Pairs)

Real World Assignment

1. Identify and classify kinematic pairs and determine DOF of mechanisms used in a bicycle or IC engine.
2. Analyze different inversions of the slider-crank mechanism in real machines like pumps and shapers.
3. Replace higher pairs in cam or gear systems with equivalent lower pair mechanisms and compare motion.

Exemplars / Practical Applications

Mechanisms used in IC engines, pumps, and quick return mechanisms demonstrate real-life kinematic chains and inversions.

Unit II	Kinematic Analysis of Mechanisms: Analytical Method & Graphical Method	(07 Hours)

Analytical methods: Displacement, velocity and acceleration analysis of slider crank Mechanism. Vector and Complex Algebra Methods (Theoretical Treatment only).

Graphical methods: Displacement, velocity and acceleration analysis of mechanisms by Relative Velocity Method (Mechanisms up to 6 Links), Coriolis component of Acceleration (Theoretical treatment only)

Instantaneous Centre of Velocity, Kennedy's Theorem, Angular Velocity ratio Theorem, Analysis of mechanism by ICR method (Mechanisms up to 6 Links)

Real World Assignment

1. Determine velocity and acceleration of piston in an IC engine using graphical or analytical methods.
2. Perform motion analysis of a crank-rocker mechanism used in conveyor or machinery systems.
3. Locate instantaneous centers in mechanisms like wiper mechanism / single slider crank mechanism in I.C. engine and analyze motion transmission.

Exemplar / Practical Applications

Motion analysis of IC engines, robotic arms, and industrial machinery helps in predicting velocity and acceleration of links.

Unit III	Synthesis of Mechanisms	(07 Hours)

Steps in Synthesis: Type synthesis, Number Synthesis, Dimensional synthesis, Tasks of Kinematic synthesis - Path, function and motion generation (Body guidance), Precision Positions, Chebychev spacing, Mechanical and structural errors

Graphical Synthesis: Inversion and relative pole method for three-position synthesis of Four-Bar and Single Slider Crank Mechanisms

Analytical Synthesis: Three-position synthesis of the Four-Bar mechanism using Freudenstein's equation

Real World Assignment

1. Design a four-bar mechanism for the windshield wiper to achieve the required angular motion.
2. Synthesize a mechanism for path generation in applications like welding or cutting.
3. Develop a linkage mechanism for pick-and-place automation using precision positions.

Exemplars / Practical Applications

Mechanism synthesis is applied in windshield wipers, folding systems, and industrial automation linkages.

Unit IV	Kinematics of Gears	(08 Hours)

Introduction: Classification, terminology, law of gearing, involute and cycloidal tooth profile,

Spur Gear: path of contact, arc of contact sliding velocity, Interference and undercutting, Minimum number of teeth to avoid interference, Force Analysis (theoretical treatment only)

Helical and Spiral Gears: Terminology, Geometrical Relationships, virtual number of teeth for helical gears

Bevel Gear & Worm and Worm Wheel: Terminology, Geometrical Relationships

Gear Train: Types, Analysis of Epicyclic gear Trains, Holding torque - simple, compound and Epicyclic gear Trains, compound Epicyclic gear Train

Real World Assignment

1. Analyse gear ratios and torque transmission in an automobile gearbox or industrial gear trains.
2. Study interference in gears and suggest design modifications to avoid undercutting.
3. Evaluate the working of the epicyclic gear train used in differential or automatic transmission systems.

Exemplars / Practical Applications

Gear systems in automobiles, industrial gearboxes, and differential mechanisms illustrate power transmission applications.

Unit V	Cams & Followers	(08 Hours)

Introduction: Types of cams and followers, and their classification, analysis of standard motions to the follower,

Cam Profile: Determination of cam profiles for different follower motions

Methods of control: pressure angle, radius of curvature and undercutting. Jump phenomenon of Eccentric cam,

Real World Assignment

1. Design a cam profile for IC engine valve timing based on the given motion requirements.
2. Develop a cam mechanism for automated machines like packaging or printing systems.
3. Analyze pressure angle and follower motion to avoid undercutting and jumping in cam systems.

Exemplars / Practical Applications

Cam mechanisms are widely used in IC engines, textile machines, and automated production equipment.

Learning Resources

Text Books:

1. S. S. Rattan, "Theory of Machines", Third Edition, McGraw Hill Education (India) Pvt. Ltd., New Delhi.
2. Bevan T, "Theory of Machines", Third Edition, Longman Publication
3. G. Ambekar, "Mechanism and Machine Theory", PHI
4. J. J. Uicker, G. R. Pennock, J. E. Shigley, "Theory of Machines and Mechanisms", Fifth Edition, International Student Edition, Oxford

Reference Books:

1. Ghosh Malik, "Theory of Mechanism and Machines", East-West Pvt. Ltd.
2. Hannah and Stephans, "Mechanics of Machines", Edward Arnolde Publication
3. R. L. Norton, "Kinematics and Dynamics of Machinery", First Edition, McGraw Hill Education (India) P Ltd. New Delhi
4. Sadhu Singh, "Theory of Machines", Pearson
5. Dr. V. P. Singh, "Theory of Machine", Dhanpatrai and Sons
6. C. S. Sharma & Kamlesh Purohit, "Theory of Machine and Mechanism", PHI.

MOOC / NPTEL/ YouTube Links: -

1. Kinematics of Machines – IIT Kanpur (NPTEL): https://nptel.ac.in/courses/112104121
2. Kinematics of Mechanisms and Machines – IIT Kharagpur (NPTEL): https://onlinecourses.nptel.ac.in/noc25_me46/preview
3. Theory of Mechanisms – IIT Madras (NPTEL): https://nptel.ac.in/courses/112106270
4. Mechanism and Robot Kinematics – NPTEL: https://onlinecourses.nptel.ac.in/noc22_me108/preview

Savitribai Phule Pune University Third Year of Mechanical Engineering (2024 Pattern)				
PCC303-MEC: Design of Machine Elements				
Teaching Scheme		**Credit**	**Examination Scheme**	
Theory	**4 Hours/Week**	**4**	**CCE**	**30 Marks**
Practical	**NA**		**End-Semester**	**70 Marks**

Prerequisite Courses, if any:

The basics of material elastic behavior, stress, strain, its relationship, failure modes, different theories of failure and its applications. The design cycle, basis of design considerations like strength, rigidity, manufacture, assembly and cost, standards and codes. The preferred sizes and series, tolerances and types of fits. Construction of SMD and BMD. Roots of equations, Interpolation rule.

Course Objectives:

1. **UNDERSTAND** various design considerations, design procedures.
2. **SELECT** materials for a specific application.
3. **EVALUATE** the stresses in machine components due to various types of loads and failure.
4. **DESIGN** various machine components such as shafts, couplings, keys, screws, joints, springs.
5. **ANALYZE** machine components subjected to variable loading for finite and infinite life.

Course Outcomes:

After successful completion of the course, learner will be able to:

CO. 1 **DESIGN** levers and components subjected to eccentric loading by selecting appropriate material.

CO. 2 **DESIGN** shafts, keys and couplings under different loading conditions.

CO. 3 **EVALUATE** the stresses developed in the different type of welded and threaded joints.

CO.4 **APPLY** the design procedure for different types of springs and **EVALUATE** dimensions of machine components under fluctuating loads.

CO. 5 **ANALYZE** different stresses developed in power screws and **APPLY** those in the procedure to design screw jack.

Course Contents

Unit I	**Fundamentals of Machine Design and Material Selection**	**(07 Hours)**

Selection of materials and factor of safety, Service factor, Design of hand / foot lever, lever for safety valve, bell crank lever, Design of components subjected to eccentric loading., Design process , Design considerations, Engineering materials and their properties, Stress concentration, Static and fluctuating loads.

Real World Assignment

1 Determine whether an elevator cable is safe under the maximum passenger load.

2 Determine the factor of safety of motorcycle side stand and verify whether design is safe.

3 Identification of different engineering materials used in various parts of two wheeler with reasoning

4 Ergonomic Lever Design for Hand Lever or Foot Lever for bore-well pump

5 The Material selection and analysis of failed mechanical component such as snapped bolt, fan blade etc.

6 Stress Concentration for plate with a central hole

Exemplar / Practical Applications

Material Selection in Industry, Bell Crank Lever for Bicycle Braking Systems, Lever for Safety Valve for Industrial Boilers, Eccentric Loading in C-Clamps, Fluctuating Loads in Automobile Leaf Springs, Service Factor for different mechanical systems.

Unit II	**Design of Shafts, Keys and Couplings**	**(07 Hours)**

Shaft design on the Strength basis, torsional rigidity basis and lateral rigidity basis, Design of shaft as per A.S.M.E. code. Design of square and rectangular keys, Kennedy key and splines. Design of Flange Coupling and Bushed-Pin Flexible Coupling.

Real World Assignment

1 Design of shaft for real world applications like lathe, pump , automobile etc.
2 Design, and analyze keys used in real mechanical systems for torque transmission.
3 Identify different types of couplings used in the transmission system and justify their use.

Exemplar / Practical Applications

1) Automotive engines and transmissions
2) Industrial machinery like conveyor systems and pumps
3) Agricultural equipment, including tractors and harvesters
4) Automotive powertrains in electric vehicles

Unit III	Design of Mechanical Joints	(08 Hours)

Introduction to threaded joints, Bolts of uniform strength, locking devices, eccentrically loaded bolted joint in shear, Eccentric load perpendicular and parallel to axis of bolt, Eccentric load on circular base. Applications of joints in mechanical systems

Introduction to welded joints, Strength of butt, parallel and transverse fillet welds, axially loaded unsymmetrical welded joints, Eccentric load in plane of welds, Welded joints subjected to bending and torsional moments. Design of cotter and knuckle joints

Real World Assignment

1. Industrial Visit to workshop
2 Design a cotter joint for bicycle so as to transmit power from pedal to axle of bicycle.
3. Design a knuckle joint for tractor and trailer so that tractor can pull the trailer of 3 ton. (Empty weight 0.5 ton + material weight 2.5 ton).

Exemplar / Practical Applications

Steam Engine -connecting piston rod to cross head, Pump-piston rod to tail pump rod (Cotter joint), automotive steering mechanism, train coupling, tractor -trolley linkage (knuckle joint), Pressure Vessels, pipe lines, automotive frames (welded joints).

Unit IV	Design of Springs and Mechanical Components under Variable Loads	(08 Hours)

Springs: Types and applications of springs, Stress and deflection equations for helical compression Springs, Springs in series and parallel, Design of helical springs, concentric helical springs, surge in spring, Design of Multi-leaf springs, Nipping of Leaf springs, Shot Peening.

Analysis of machine elements under variable loads: Fatigue Failure, Stress-Life (S–N) Curve and Endurance Limit, Factors Affecting Endurance Strength (Modifying Factors and Notch Sensitivity), Reversed Stress Concept, Fatigue Failure Theories: Soderberg, Goodman, and Gerber Criteria, Modified Goodman Diagram for Design Applications, Design for Finite and Infinite Life, Cumulative Damage in Fatigue, Fatigue Design Under Combined Stresses (Theoretical Approach)

Real World Assignment

1 Design a helical compression spring for a suspension system and analysis of Compression Spring Used in Motorcycle Suspension
2 study construction and verify basic design calculations of leaf springs.
3 Comparative Study of Helical Spring for various applications
4 Suspension system in automobile (Two wheeler / Car)
5 Fatigue Design of an Automotive Drive Shaft
6 Fatigue Analysis of a Connecting Rod

Exemplar / Practical Applications

Design of Helical Compression Spring for Automotive Suspension, Design of Multi-Leaf Spring for Light Commercial Vehicle, Fatigue Design of Rotating Shaft Under Variable Loading, Fatigue Life Estimation Using Cumulative Damage (Miner's Rule)

Unit V	Design of Power Screw	(08 Hours)

Terminology of Power Screw, Torque analysis and Design of power screws with square and trapezoidal threads, Collar friction torque, Self-locking screw, Efficiency of square threaded screw, Efficiency of self-locking screw, Design of screw, nuts and C-Clamp. Design of screw jack, Differential and Compound Screw and Re-circulating Ball Screw **(Theoretical treatment only).**

Real World Assignment

1 Torque Requirement and Efficiency Estimation of a Bench Vice Screw Mechanism
2 Analysis of C-Clamp Screw and Collar Friction Effects
3 Design a Power screw for a Hydraulic Press
4 Design of Automotive steering gear (Recirculating Ball Type)
5 Design of a 2-Ton Mobile Scissor Lift Power Screw

Exemplar / Practical Applications

The car Jack, machine vise, Large mechanical Press.

Learning Resources

Text Books:

1 Bhandari V.B., Design of Machine Elements, Tata McGraw Hill Publication Co. Ltd.

2 Shigley J.E. and Mischke C.R., Mechanical Engineering Design, McGraw Hill Publication Co. Ltd.

Reference Books:

1 Spotts M.F. and Shoup T.E., Design of Machine Elements, Prentice Hall International.

2. Juvinal R.C., Fundamentals of Machine Components Design, John Wiley and Sons.

3. Black P.H. and O. Eugene Adams, Machine Design, McGraw Hill Book Co. Inc.

4. Willium C. Orthwein, Machine Components Design, West Publishing Co. and Jaico Publications House.

5. Hall A.S., Holowenko A.R. and Laughlin H.G, Theory and Problems of Machine Design, Schaum's Outline Series.

6. C. S. Sharma and Kamlesh Purohit, Design of Machine Elements, PHI Learing Pvt. Ltd.

7. D. K. Aggarwal & P. C. Sharma, Machine Design, S.K Kataria and Sons.

8. P. C. Gope, Machine Design: Fundamentals and Applications, PHI Learing Pvt. Ltd.

9. Design Data - P.S.G. College of Technology, Coimbatore.

10. K. Mahadevan, K. Balveera Reddy, Design Data Handbook for Mechanical Engineers, CBS Publishers.

MOOC / NPTEL/YouTube Links: -

https://www.youtube.com/watch?v=ofmbhbVCU qI&list=PL3D4EECEFAA99D9BE&index=3

https://www.youtube.com/watch?v=SL21aDqgs8Q

https://www.youtube.com/watch?v=TPURJnlekeo

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PCC304-MEC: Manufacturing Process-II

Teaching Scheme		Credit	Examination Scheme	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End-Semester**	**70 Marks**

Prerequisite Courses, if any:

- Workshop Practices, Manufacturing Processes-I

Course Objectives:

1. To UNDERSTAND the use of multi point cutters in gear manufacturing.
2. To APPLY knowledge of polymers and composite processing techniques.
3. To UNDERSTAND the concepts of modern machining processes.
4. To INTRODUCE the 3D printing techniques used in industry.
5. To UNDERSTAND the concept of locating the components on machine.

Course Outcomes:

After successful completion of the course, learner will be able to:

CO1. DECIDE the appropriate cutter, method for gear cutting and able to DETERMINE the cutting parameter using indexing method.

CO2. CATEGORIZE the polymer process according to product and able to DEVELOP concept for composite fabrication.

CO3. DETERMINE the suitable modern machining process for particular application and EXAMINE the material removal rate.

CO4. CLASSIFY the different 3D printing techniques and able to DEVELOP a product by using the 3D printing techniques.

CO5. DESIGN and DEVELOP the jig or fixture according to need of the component used in machining.

Course Contents

Unit I	Multipoint cutting tools and Gear Manufacturing	(08 Hours)

Introduction of multi point cutting tools, Nomenclature of multipoint cutting tools like milling, drilling, reaming and taps, Selection criteria for multipoint cutters.
Introduction and classification of gear manufacturing, Gear milling, standard cutters and limitations, Indexing and numerical on indexing, Gear Hobbing, Gear Shaping, Gear Shaving and Gear Grinding processes,

Real World Assignment

CCE Activities: Prepare a excel sheet for indexing method and students should produce spur gear on a milling machine.

Unit II	Polymer and composite Processing	(07 Hours)

Thermoplastics and Thermosetting, Moulding: Compression moulding, Transfer moulding, Blow moulding, Injection moulding - Process and equipment Extrusion of Plastic: Type of extruder, extrusion of film, pipe, Cable and Sheet – Principle Pressure forming and Vacuum forming. Introduction to composites, Composite properties, Matrices, Fiber reinforcement. Composite Manufacturing Processes: Hand lay-up Process, Spray lay-up, Resin transfer moulding, Pultrusion, and Compression moulding process, Vacuum impregnation process, Processing of metal matrix composites, Fabrication of ceramic matrix composites, Carbon-carbon composites, Polymer matrix and nano-composites.

Real World Assignment

CCE Activities: Prepare a simple composite component by using any one method as individual or group task.

Unit III	Modern Machining Processes	(07 Hours)

Introduction to modern manufacturing processes, Need and classification of modern manufacturing methods. Introduction, Working Principle, equipment, process parameters, material removal rates of Mechanical Energy Process machining processes : Abrasive Jet Machining (AJM), Water Jet Machining (WJM), Ultra Sonic Machining (USM), Energy Assisted Modern Fabrication Process : Laser beam machining (LBM), Focused Ion beam (FIB) Electro-chemical Machining Process : Electro chemical machining (ECM), Photochemical machining (PCM) Electro-thermal Machining Process : Electric discharge machining (EDM), Wire Electric Discharge Machining (W-EDM)

Real World Assignment

CCE Activities: Industrial visit to any one modern manufacturing process unit as individual or group task. Students should be able to understand process parameters and write report of the visit.

Unit IV	Additive Manufacturing	(07 Hours)

Introduction to AM, Classification of AM Processes (Process-based, material form based, application-based - direct and indirect processes and Micro- and Nano-additive processes), Light-Based Photo-curing: Stereolithography (SLA), Digital Light Processing (DLP), Laser-Based Melting: Selective Laser Sintering (SLS), Direct Metal Laser Sintering (DMLS), Selective Laser Melting (SLM). Extrusion-Based Deposition: Fused Deposition Modeling (FDM). Inkjet(droplet)-Based Deposition and Fusion: Multi-jet Modeling (MJM), Polyjet Printing, Nanoparticle Jet, Quality considerations and Post-Processing techniques: Requirements and Techniques, Support Removal, Sanding, Acetone treatment, Polishing.

Real World Assignment

CCE Activities: Prepare a simple component staring from the geometry to product on any 3D printing machine.

Unit V	Jig and Fixture Design	(07 Hours)

Importance of jigs and fixtures in mass production, Concept of Interchangeability, degree of freedom, six point principle or 3-2-1 location method, Fundamental principles for the design of jigs and fixtures. Jigs- Definition, locating methods and devices, Clamping principles, Drill bushes, Types of jigs- Template jig, Leaf jig, Box Jig or Tumble Jig, Indexing Jig, Angular post jig. Fixtures: Definition. Design principles of fixture, Types of fixtures- Turning fixture, Grinding fixture, Welding fixture, Indexing fixtures, Inspection fixtures. Numerical on simple jig or fixture design

Real World Assignment

CCE Activities: Students should be able to design a jig or fixture for simple products.

Learning Resources

Text Books:

1. P. N. Rao, "Manufacturing Technology Vol. I & II" , Tata McGraw Hill Publishers
2. P. C. Sharma, "Production Engineering", Khanna Publishers
3. Manufacturing Science" A. Ghosh, and A.K. Mallik, Affiliated East-West Press Pvt. Ltd. New Delhi.
4. Elanchezhian, C., T. Sunder Selwyn, and B. Vijaya Ramnath. Design of Jigs, Fixtures and Press Tools. Eswar press, 2004.

Reference Books:

1. R.K.Jain, "Production Technology" Khanna Publication
2. Brent Strong, "Fundamentals of Composites Manufacturing: Materials, Methods", SME Book series
3. Materials and Processes in Manufacturing & quot; (8th Edition),E.P. DeGarmo, J. T Black, R.A. Kohser, Prentice Hall of India, New Delhi (ISBN 0-02-978760).
4. Nontraditional Manufacturing Processes", G.F.Benedict, Marcel Dekker, Inc. New York (ISBN 0-8247-7352-7).

MOOC / NPTEL/ YouTube Links: -

https://nptel.ac.in/courses/112104195

https://nptel.ac.in/courses/112107219

https://nptel/courses/video/112107078

https://nptel/courses/video/112104197

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PCC 305-MEC: Metrology and Quality Control

Teaching Scheme		Credit	Examination Scheme	
Theory	3 Hours/Week	3	CCE	30 Marks
Practical	NA		End Sem	70 Marks

Prerequisite Courses, if any:

- Fundamentals of engineering measurements and instrumentation, Basic knowledge of manufacturing processes and machine tools, statistics and probability concepts.

Course Objectives:

After completing this course, students will be able to:

1. UNDERSTAND modern measurement systems, standards, calibration, and uncertainty analysis used in Industry 4.0 environments.
2. APPLY advanced metrology tools such as CMM, machine vision, and non-contact measurement techniques for industrial inspection.
3. COMPREHEND quality management principles, philosophies, and tools for process improvement.
4. ANALYZE and CONTROL manufacturing processes using statistical quality control techniques and acceptance sampling.
5. IMPLEMENT advanced quality engineering tools such as FMEA, Lean, Six Sigma, and digital quality systems.

Course Outcomes:

After successful completion of the course, students will be able to:

CO1: APPLY principles of metrology, calibration and measurement uncertainty in engineering applications

CO2: UNDERSTAND and USE advanced metrology systems like CMM and non-contact measurement techniques for inspection

CO3: IMPLEMENT quality tools and methodologies for continuous improvement

CO4: ANALYZE process performance using statistical quality control and sampling techniques

CO5: APPLY advanced quality engineering tools such as FMEA, Lean Six Sigma, and digital quality systems

Course Contents

Unit I	Modern Measurement Systems and Metrology Fundamentals	(08 Hours)

Metrology Fundamentals and Modern Measurement Systems: Role of metrology in smart manufacturing and Industry 4.0, measurement standards and traceability (ISO/BIS standards), types and sources of errors, measurement uncertainty analysis, accuracy, precision, repeatability and reproducibility (R&R concept), calibration: digital calibration systems and documentation.

Measurement Instruments and Comparators: Digital instruments such as Vernier caliper, micrometer and height gauge, Types of gauges-plain plug gauge, ring gauge, snap gauge, limit gauge and gauge materials comparators: mechanical, pneumatic and electrical (LVDT).

Limits, Fits and Geometric Tolerance: Limits, fits and tolerances, Introduction to Geometric Dimensioning and Tolerance (GD&T) symbols and industrial applications.

CCE Activities:

Measurement of dimensions of given components using digital instruments such as Vernier calliper, micro meter, height gauge, and dial gauge

Unit II	Advanced Metrology and Industrial Inspection Systems	(08 Hours)

Coordinate Measuring Machines (CMM): Types of CMM such as bridge, gantry, portable and horizontal arm, types of probes including touch trigger, scanning and optical probes, applications in reverse engineering and inspection.

Optical and Non-Contact Metrology: Machine vision systems including image processing basics and industrial inspection applications, profile projector and toolmaker's microscope, 3D scanning technologies such as laser scanning and structured light.

Thread and Gear Metrology: Thread parameters such as major diameter, minor diameter and pitch diameter, introduction to optical and CMM-based thread measurement, gear metrology including gear errors

Surface Metrology: Surface texture and parameters such as Ra, Rz and Rt, modern surface measuring instruments including stylus-based instruments, optical surface profilers.

Real World Assignment

CCE Activities:

Case study on Industrial applications of CMM, machine vision systems, and non-contact metrology in inspection, reverse engineering, and quality control

Unit III	Introduction to Quality and Quality Tools	(08 Hours)

Introduction to Quality: Quality Concepts, Quality dimensions, Statements, Cost of quality & value of quality, Deming"s cycles & 14 Points, Juran Trilogy approach, Seven Quality Tools, Introduction to New Seven Tools, Quality Circle, 5S, Kaizen, Poka yoke, Kanban, JIT, QMS (ISO 9000, TS16949, ISO14000). Criteria for Quality Award (National & International)

Real World Assignment

CCE Activities:

Student should select and apply any one technique such as 5S, Kaizen, Poka-Yoke, or Kanban for process improvement

Unit IV	Statistical Quality Control	(07 Hours)

Statistical quality control: Statistical concept, Frequency diagram, Concept of variance analysis, Control, Chart for Variable (X & R Chart) & Attribute (P & C Chart), Process capability (Indices: cp, cpk, ppk), Statistical Process Control and six sigma.

Acceptance Sampling: Sampling Inspection, OC Curve and its characteristics, sampling methods, Sampling Plans, calculation of sample size, AOQ, Probability of acceptance. (Numerical on control charts and sampling)

Exemplars

CCE Activities:

Preparation and interpretation of control charts using statistical software, and analysis of process capability.

Unit V	Advanced Quality Engineering	(08 Hours)

Advanced Quality Tools:

Failure Mode and Effects Analysis (FMEA), Failure Mode, Effects and Criticality Analysis (FMECA), steps involved in FMEA, Risk Priority Number (RPN), severity, occurrence and detection ratings, basic symbols, and case studies.

Lean and Six Sigma Integration:

Overview of Six Sigma (DMAIC methodology), introduction to Lean principles, waste identification and integration of Lean and Six Sigma for process improvement.

Digital Quality and Industry 4.0:

Introduction to digital quality management systems, real-time quality monitoring, application of IoT in quality control, and concepts of smart inspection and data-driven decision making.

Real World Assignment

CCE Activities:

Case study on application of FMEA/FMECA in manufacturing or service systems

Learning Resources

Text Books:

1. Jain R.K., Engineering Metrology, Khanna Publication.
2. C. Gupta, Engineering Metrology, Dhanpath Rai.
3. Bewoor A. K. and Kulkarni V. A., Metrology and Measurements, Tata McGraw hill Publication.
4. Juran J. M., Quality Handbook, McGraw Hill Publications.

Grant S.P., Statistical Quality Control, Tata McGraw hill Publication.

Reference Books:

1. Narayana K.L., Engineering Metrology.
2. Galyer J.F & Shotbolt C.R., Metrology for engineers.
3. Gupta I.C., Engineering Metrology, Dhanpatrai Publiartions.
4. Judge A.W., Engineering Precision Measurements, Chapman and Hall
5. Francis T. Farago, Mark A. Curtis, Handbook of dimensional measurement.
6. ASTME, Handbook of Industrial Metrology, Prentice Hall of India Ltd.
7. Connie Dotson, Fundamentals of Dimensional Metrology, Thamson Publn., 4th Edition.
8. Basterfield D. H., Quality control, Pearson Education India, 2004.
9. Kulkarni V. A. and Bewoor A. K., Quality Control, John Wiley Publication.
10. Harrison M. Wordsworth, Stefeen Godfrey, Modern Methods for Quality control and Improvement, Willy Publication.

MOOC / NPTEL/ YouTube Links: -

1. nptel.ac.in/courses/112106179;
2. www.nptelvideos.in/2012/12/mechanical-measurements-and-metrology.html
3. www.me.iitb.ac.in/~ramesh/courses/ME338/metrology6.pdf; nptel.ac.in/courses/110101010/;
4. freevideolectures.com › Mechanical › IIT Madras nptel.ac.in/courses/112107143/37;

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PCC 306-MEC: Industrial Fluid Power Lab

Teaching Scheme		Credit	Examination Scheme	
Theory	**NA**	**1**	**CCE**	**NA**
Practical	**2 Hours/Week**		**PR**	**50 Marks**

Prerequisite Courses, if any:

- Fluid Mechanics, Machine Tools, Manufacturing Processes

Course Objectives:

1. **PERFORM** experiments to **UNDERSTAND** the working principles of hydraulic and pneumatic components.
2. **DEVELOP** skills to assemble, operate, and analyze basic hydraulic and pneumatic circuits.
3. **EVALUATE** performance characteristics of fluid power devices such as pumps and control valves.
4. **DESIGN** electro-hydraulic and electro-pneumatic circuits using industrial standards and catalogues.
5. **APPLY** modern tools such as simulation software and IoT platforms for monitoring and control of fluid power systems.

Course Outcomes:

After successful completion of the course, learner will be able to:

CO1: **IDENTIFY** and **INTERPRET** symbols and specifications of hydraulic and pneumatic components as per ISO/IS/JIC standards.

CO2: **ASSEMBLE** and **DEMONSTRATE** basic hydraulic and pneumatic circuits for speed, pressure, and sequence control applications.

CO3: **CONDUCT** experiments to **EVALUATE** performance characteristics of pumps and control valves and **ANALYZE** the results.

CO4: **DESIGN** and **SIMULATE** electro-hydraulic and electro-pneumatic circuits using manufacturer catalogues and software tools.

CO5: **IMPLEMENT** basic automation and IoT-based control for fluid power systems and document experimental findings professionally.

Sr.No.	Name of Experiment	(02 Hours)

1. Fluid Power Components with IS/JIC/ISO Symbols
2. Experiments on hydraulic trainer: Simple Hydraulic Circuit, Regenerative circuit, Speed control circuits, Sequencing Circuit
3. Experiments on pneumatic trainer: Automatic reciprocating circuit, Pneumatic circuits using Shuttle/Quick exhaust/Two pressure valve, Pneumatic clamp
4. Determination of performance Characteristics Positive Displacement Pump
5. To test Directional / Flow / Pressure Control Valve (Any One)
6. Study of Hydraulic Press Set-Up using Accumulator and Intensifier
7. Design Electrohydraulic and Electropneumatic Circuits
8. Design of hydraulic / pneumatic circuits using the manufacturer’s catalogue
9. IoT based systems to operate electro-pneumatic/electro-hydraulic circuits
10. Industrial Visit / Experiments using Virtual Labs

Note: Conduct any eight experiments from the above-mentioned list

Learning Resources

Text Books:

1. Anthony Esposito, "Fluid Power with Applications", Pearson Prentice Hall, 2009, Edition 7, ISBN 0135136903
2. S. R. Majumdar, "Oil Hydraulic Systems: Principles and Maintenance", McGraw-Hill Edu., 2018, Edition 1, ISBN 0071406697
3. S. R. Majumdar, "Pneumatic Systems: Principles and Maintenance", McGraw-Hill Education, 1995, Edition 1, ISBN 0074602314

Reference Books:

1. John J. Pippenger and Tyler G. Hicks, "Industrial Hydraulics", McGraw-Hill (Gregg Division), 1979, Edition 3, ISBN 0070501408
2. S. Ilango, "Introduction to Hydraulics and Pneumatics", Prentice-Hall of India Pvt Ltd, 2007, Edition 1, ISBN 8120329877
3. Andrew Parr, "Hydraulics and Pneumatics: A Technician's and Engineer's Guide", Jaico Pub. House, 2005, Edition 1, ISBN 8172241895 .

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

MDM 321-MEC: Industrial Robotics

Teaching Scheme		Credit	Examination Scheme	
Theory	**NA**	**1**	**PR**	**50 Marks**
Practical	**2 Hours/Week**		**End Sem**	**-**

Prerequisite Courses, if any:

- Engineering Mechanics: understanding of forces, motion, and rigid body dynamics
- Theory of Machines: concepts of links, joints, and motion analysis
- Manufacturing Processes: awareness of production systems and industrial operations
- Basic Electrical & Electronics Engineering: fundamentals of sensors, actuators, and control components

Course Objectives:

1. To EXPOSE students to real industrial robotic systems and automation practices
2 .To DEVELOP hands-on skills in robot operation, programming, and integration
3 .To UNDERSTAND robot deployment in manufacturing and Industry 4.0

Course Outcomes:

After successful completion of the course, learner will be able to:

CO. 1 EXPLAIN the fundamentals of industrial robotics, robot classifications, specifications, and applications observed in real industrial environments.

CO. 2 APPLY knowledge of robot anatomy, drive systems, and end effectors to analyze and propose suitable configurations for industrial tasks.

CO. 3 ANALYZE the role of **sensors, vision systems, and safety mechanisms** in robotic systems and evaluate their effectiveness in industrial applications.

CO. 4 DEVELOP and EXECUTE **basic robot programs and simulations** for industrial operations such as pick-and-place and path planning.

CO. 5 DESIGN and EVALUATE a complete robotic work cell by integrating robot selection, layout planning, cycle time analysis, and safety considerations.

Course Contents

Experiment-1		**(02 Hours)**

Title: Study and Comparison of Industrial Robot Types and Their Specifications

Objectives:

1. To understand different classifications of industrial robots (Articulated, SCARA, Cartesian, Delta, Collaborative).
2. To study robot specifications such as DOF, payload, repeatability, accuracy, and workspace.
3. To compare robots based on their suitability for applications.

Experiment-2		**(02 Hours)**

Title: Study of Industrial Robot Applications and Automation Levels in Smart Manufacturing

Objectives:

1. To study various industrial applications of robots.
2. To understand levels of automation in manufacturing systems.
3. To explore the concept of Industry 4.0 and smart factories.

Experiment-3		**(02 Hours)**

Title: Virtual Modeling of Robot Links, Joints, and Coordinate Systems using Open-Source Software

Objectives:
1. To model a robot structure using links and joints (revolute & prismatic).
2. To understand coordinate systems and robot motion.
3. To analyze Degrees of Freedom (DOF) and workspace.

Experiment-4		**(02 Hours)**

Title: Study of Robot Drive Systems, Transmission Mechanisms, and End Effectors

Objectives:
1. To study different robot drive systems: electric, hydraulic, pneumatic.
2. To understand transmission systems such as gears, belts, and harmonic drives.
3. To examine various end effectors and tooling used in industrial robots.

Experiment-5		**(02 Hours)**

Title: Simulation of robotic arm

Objectives:
1. To analyze forward kinematics of robotic arm

Experiment-6		**(02 Hours))**

Title: Determine end effector position using inverse kinematics

Objectives:

To determine joint angles for a given end effector position

Exemplar / Practical Applications:

1)Pick and place robots, 2) Transportation of materials, 3) Welding torch

Experiment-7		**(02 Hours)**

Title: Study and Virtual Implementation of Sensors and Vision Systems for Robotic Inspection

Objectives:
1. To understand different types of sensors used in robotics.
2. To study basic image processing for vision systems.
3. To simulate sensor-based inspection and object detection.

Experiment-8		**(02 Hours)**

Title: Study of Industrial Robot Safety Standards and Simulation of Human-Robot Collaboration

Objectives:
1. To understand industrial safety norms (ISO standards overview).
2. To study safety in human-robot collaboration.
3. To simulate safe interaction between humans and robots.

Exemplar / Practical Applications:

1)Surgical robotics, 2)Navigation systems, 3) Automotive and pharmaceutical lines

Experiment-9		**(02 Hours)**

Title: Programming Basic Robot Motions using Open-Source Simulation

Objectives:
1. To understand basic robot programming concepts.
2. To perform joint and linear movements of a robot.
3. To visualize robot motion and trajectory.

Experiment-10		**(02 Hours)**

Title: Programming a Pick-and-Place Task using Open-Source Robot Simulator

Objectives:

1. To program a simple industrial task.
2. To understand sequencing and logic in robot programming.
3. To simulate material handling operation.

Exemplar / Practical Applications:

1)Aerospace parts , 2)Palletizing, 3)Bottling plants, 4)Milling of engine blocks

Experiment-11		**(02 Hours)**

Title: Design of Robotic Work Cell and Optimization of Layout

Objectives:

To understand components of a robotic work cell.

To design an efficient layout.

To analyze cycle time and productivity.

Exemplar / Practical Applications:

1)Automotive assembly design, 2)CNC machine tending, 3)Flexible warehousing,

Experiment-12		**(02 Hours)**

Title: Pick and Place Operation Using Teach Pendant

Objective:

1. To program and execute a simple pick-and-place task using robot

Experiment-13		**(02 Hours)**

Title: Robot Path Programming (Point-to-Point and Continuous Path)

Objective:

1. To study different robot motion types and path control using robot

Experiment-14		**(02 Hours)**

Title: Effect of robot speed on cycle time and productivity

Objective:

1. To study the effect of robot speed on cycle time and productivity.

Learning Resources

Text Books:

1 Industrial Robotics: Technology, Programming and Applications” by Mikell P. Groover

2 A Textbook of Industrial Robotics” by Ganesh S. Hegde

3 Industrial Automation and Robotics: Techniques and Applications” by Kaushik Kumar & B. Sridhar Babu

Reference Books:

1 Handbook of Industrial Robotics” by Shimon Y. Nof

2. Industrial Robotics in Smart Manufacturing” by Amit Kumar Tyagi

3. Robot Manipulators: Mathematics, Programming, and Control by Richard P. Paul

4. Introduction to Robotics: Mechanics and Control by John J. Craig

5. Robotics, Vision and Control by Peter Corke

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

MDM 322-MEC: Smart Mechatronics Systems

Teaching Scheme		Credit	Examination Scheme	
Theory	**NA**	**1**	**PR**	**50 Marks**
Practical	**2 Hours/Week**		**CCE**	**NA**

Prerequisite Courses, if any:

- Applied Mechanics, • Strength of Materials , Thermodynamics Fluid Mechanics Machine Design basics etc.

Course Objectives:

After successful completion of the course, students will be able to:

CO1: To INTRODUCE modeling and analysis of mechanical systems for understanding dynamic behavior.

CO2: To DEVELOP knowledge of open-loop and closed-loop control systems and their practical implementation.

CO3:To implement PID control techniques for improving system performance in real-time applications.

CO4: To DESIGN and DEVELOP PLC-based industrial automation systems using sensors and actuators.

CO5:To ACQUIRE, MONITOR and ANALYZE data using data acquisition systems and interfacing tools.

Course Outcomes:

After successful completion of the course, students will be able to:

1. MODEL and ANALYZE mechanical systems using mathematical and simulation tools.
2. DEMONSTRATE closed-loop control systems.
3. IMPLEMENT and TUNE PID controllers for dynamic systems.
4. DEVELOP PLC programs for industrial automation applications.
5. ACQUIRE and VISUALIZE data using data acquisition systems

Course Contents

Experiment-1	**Modeling of Mechanical System (Mass-Spring-Damper)**	**(02 Hours)**

Objective:

To model a mechanical system and analyze its dynamic behavior.

Task

1. Develop mathematical model of mass-spring-damper system
2. Simulate system using MATLAB/Simulink or equivalent
3. Study response for different parameters

Components Required:

1. Computer with MATLAB/Simulink (or Scilab)
2. Experimental kit (optional spring-mass setup)

Applications:

1. Vehicle suspension system
2. Vibration analysis in machines

Experiment-2	**Closed Loop Control System (Speed Control)**	**(02 Hours)**

Objective: To implement a closed loop control system.

Task:

1. Measure motor speed using sensor (encoder)
2. Compare with reference input
3. Adjust control signal

Components Required:

1. Arduino
2. DC motor with encoder
3. Motor driver
4. Power supply

Applications:

1. Industrial motor control
2. Robotics

Experiment-3	PID Controller Implementation (Simulation)	(02 Hours)

Objective: To understand PID controller tuning and response.

Task:

1. Implement PID controller in simulation
2. Tune Kp, Ki, Kd values
3. Analyze rise time, overshoot, settling time

Components Required: MATLAB/Simulink

Applications:

1. Process industries
2. Temperature and speed control

Experiment-4	PID Control of DC Motor (Hardware)	(02 Hours)

Objective: To implement PID control on a real system.

Task:

1. Control DC motor speed using PID algorithm
2. Compare with open loop response
3. Tune PID parameters

Components Required:

1. Arduino
2. DC motor with encoder
3. Motor driver
4. Power supply

Applications:

1. CNC machines
2. Robotics

Experiment-5	PLC Programming – Basic Operations	(02 Hours)

Objective: To develop basic PLC ladder logic.

Task:

1. Implement start/stop logic
2. Use latching and interlocking

Components Required:

1. PLC trainer kit
2. Push buttons
3. Indicator lamps

Applications: Industrial automation panels.

Experiment-6	PLC-Based Bottle Filling System	(02 Hours)

Objective: To implement real-time industrial automation.

Task:

1. Detect bottle using sensor
2. Control filling using timer
3. Move conveyor

Components Required:

1. PLC
2. Bottle filling setup
3. Sensors
4. Pump/Valve

Applications:

- Beverage industries
- Chemical processing

Experiment-7	HMI/SCADA-Based Monitoring System	(02 Hours)

Objective: To monitor and control process variables using HMI.

Task:

- Interface PLC with HMI
- Display real-time data
- Control outputs

Components Required:

- PLC
- HMI/SCADA software
- Communication cable

Applications:

- Process industries
- Automation plants

Experiment-8	Industrial Visit	(02 Hours)

Industrial Visit options for Mechatronics students (especially around nearby industrial hubs like Automotive Manufacturing Plants/Automobile plant/Process Industries etc.)

OR

Arrange the expert guest lecture.

Learning Resources

Text Books:

1.Mechatronics Principles and Applications, Godfrey Onwubolu
2.Mechatronics J. Paulo Davim

Reference Books:

1.Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering W. Bolton
2.Fundamentals of Mechatronics Musa Jouaneh

MOOC / NPTEL/ YouTube Links: -

1. https://onlinecourses.nptel.ac.in/noc25_me91/preview?utm_source=chatgpt.com, (sensors, actuators Signal conditioning ,Microcontrollers,Modeling & control systems)
2. https://youtu.be/5UNmi61jmno?si=0onNCxLmYaU1gf2D (Manufacturing + automation concepts Supplementing main course)

Savitribai Phule Pune University, Pune

Maharashtra, India

TE - Mechanical Engineering (2024 Pattern)

Semester - VI Courses

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PCC351-MEC: Computer Integrated Manufacturing

Teaching Scheme		Credit	Examination Scheme	
Theory	**4 Hours/Week**	**4**	**CCE**	**30 Marks**
Practical	**NA**		**End Sem**	**70 Marks**

Prerequisite Courses, if any:

- Solid Modelling and Drafting, Computer Aided Engineering, Industrial Engineering, Basic Programming, Machining Knowledge

Course Objectives:

1. To UNDERSTAND the evolution, need, and strategic importance of CIM. Understand factory automation and CIM networking in a global context.
2. To ANALYZE and SELECT appropriate hardware and software elements for integrated manufacturing systems.
3. To DEVELOP, SIMULATE, and INTEGRATE CNC programs with downstream and upstream CIM activities.
4. To EVALUATE the role of computers in integrating process planning, quality assurance, and production planning (MRP/ERP).
5. To Critically ASSESS the impact of Industry 4.0/5.0 technologies (IoT, AI, digital twins, cloud) on modern manufacturing enterprises and supply chains.

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

CO1 - EXPLAIN the core concepts, evolution, and components of CIM and factory automation.

CO2 - ANALYZE the role of hardware and software elements and their integration within a CIM environment.

CO3 - DEVELOP and SIMULATE CNC programs, understanding their integration with CAM, robotics, and material handling systems.

CO4 - EVALUATE integrated systems for process planning, quality control (CAI/SPC), and enterprise resource planning (ERP/MES).

CO5 - ASSESS the implications of Industry 4.0/5.0 technologies, including digital twins, IIoT, and sustainable manufacturing practices.

Course Contents

Unit I	Foundations of CIM, Automation and Networking	(08 Hours)

Foundations of CIM, Automation and Networking: Need & Evolution of CIM, CIM wheel and components. Introduction to Modern Manufacturing Paradigms: Lean, Agile, and Sustainable Manufacturing, **Automation:** Definition, Types (Fixed, Programmable, Flexible), and Strategic Reasons for Automation. Types of Production Systems. CIM networking: CIM Hardware and Software, introduction to CAD/CAM/CIM Networking, Classification of networks, Types of network topologies, CIM database, its types and DBMS. Product life cycle management, CAD-CAM Integration & Product Development in a networked environment.

Field assignment:

CIM wheel audit at a local manufacturing plant (Task to be done by group of 3-4 students)

Visit a nearby factory (auto parts, FMCG, pharma) and map its operations onto the CIM wheel. Identify which spokes (CAD, CAM, CAPP, MRP, etc.) are implemented and which are missing. Submit a gap-analysis report.

Exemplars / Practical Applications: Introduction to CIM Simulation Software: Explore a CIM simulation environment; identify key components like robots, conveyors, CNC machines, and AGVs. Map the material and information flow For completing the above assignment, any suitable simulation software like WITNESS can be used

Unit II	Hardware Integration: CNC, Robotics and Material Handling	(07 Hours)

Hardware Integration: CNC, Robotics and Material Handling: Computer Numerical Control (CNC): Principles, types, applications. Advanced CNC Programming: Part programming (manual & on versational), canned cycles, subroutines, macro programming. Integration with CAM: Toolpath generation and ost-processing. Industrial Robotics: Robot anatomy, configurations, end-effectors, sensors, and programming (basic pick-and-place). Robot work cell design and safety. Automated Material Handling Systems: Conveyors, AGVs, AS/RS.

Field assignment:

1) Students can generate CNC turning part in group of 3-4 use in various applications like aerospace, automotive , medical, defence , construction, energy

example:- stepped shaft, grooved pin with thread ,surgical instruments ,propeller shaft, gun barrel etc.

2) For CNC Milling parts Like Bracket (L shape, U shape), spacers and washers, Nameplate and tags.

Exemplars / Practical Applications

CNC Part Programming & Simulation: Modelling of Mechanical Component using any 3D CAD software, Preparing CNC part program using any CAM software, and executing it on CNC Turning CNC Part Programming & Simulation: Modelling of Mechanical Component using any 3D CAD software, Preparing CNC part program using any CAM software, and executing it on CNC milling.

Unit III	Digital Manufacturing & Simulation	(07 Hours)

Digital Manufacturing & Simulation: Introduction to Digital Manufacturing: Role of simulation, virtual commissioning, and digital twins in validating manufacturing processes. Group Technology (GT): Part families, coding and classification systems (e.g., Opitz, MICLASS). Benefits of GT in design and manufacturing. Cellular Manufacturing: Design and layout of manufacturing cells. Flexible Manufacturing Systems (FMS): Components, types, layouts, and scheduling. Quantitative analysis of FMS performance.

Field assignment:

Visit to any robotics or automation industry to showcase various automatic material handling systems to students. (Students must generate Visit report)

Exemplars / Practical Applications

Digital Twin Creation & Virtual Commissioning: Create a simple digital twin of a manufacturing process (e.g., CNC machine or conveyor). Simulate real-time data exchange and process validation

FMS Layout Design & Simulation: Design a flexible manufacturing cell for a family of parts; simulate throughout, machine utilization, and identify bottlenecks. Propose improvements For completing the above assignment, any suitable simulation software like WITNESS can be used

Unit IV	Information Integration: CAPP, CAI, ERP & MES	(07 Hours)

Information Integration: CAPP, CAI, ERP & MES: Computer Aided Process Planning (CAPP): Variant and Generative approaches. Computer Aided Inspection (CAI): Introduction to CMM, machine vision for inspection, integration with CAD. Statistical Process Control (SPC) in a networked environment. Enterprise-wide Integration: From MRP to ERP, MES (Manufacturing Execution Systems), and flow of information from shop floor to top floor

Field assignment:

Identify and categories various products around (daily used stationary product) according to Group technology classification technique. Ex: - Opitz coding system

Note: - Student must complete task in a group of 3-4 and generate Chart.

Exemplars / Practical Applications

CAPP Exercise – Process Planning: Develop a variant process plan (MRP) for a given part using a coding system (Opitz or custom). Create a route sheet with operations, machines, and tools

CMM Inspection Simulation: Simulate a coordinate measuring machine inspection routine for a given CAD part. Generate inspection report and compare with nominal dimensions or Machine Vision Based Quality Control (http://vlabs.iitkgp.ac.in/cim/exp7/index.html#)

For completing the above assignment, any suitable simulation software like WITNESS, Vab facility can be used.

Unit V	Industry 4.0/5.0, Sustainability	(07 Hours)

Industry 4.0/5.0, Sustainability & Case Studies: Industry 4.0: IIoT, Cyber-Physical Systems (CPS), Cloud-based Manufacturing, AI/ML in predictive maintenance and quality. Cybersecurity in manufacturing. Industry 5.0: Human-centricity, sustainability, and resilience, examples of CIM implementation (automotive, aerospace). Emerging trends: Additive manufacturing integration with CIM, collaborative robots (cobots).

Field assignment

Visit an Industry 4.0-enabled plant OR Study a published case study (Bosch, Siemens, Mahindra, Tata Motors)

Identify and document at least 6 components from: IoT sensors, Big Data analytics, Cloud platform, Cybersecurity measures, Digital Twin/Simulation, AR/VR, Additive Manufacturing, Autonomous robots

Map each component to its function and quantify the benefit.

Note:- students must generate component mapping table including

Industry 4.0 component, technology used, location in plant, function, observed benefits.

Exemplars / Practical Applications

Mini-Project: Integrated CIM Cell Design: Design a complete CIM cell (CNC + robot + conveyor + quality inspection) for a given product family. Present layout, program flow, cost justification, and Industry 4.0 integration

Introduction to Computer Integrated Manufacturing System:

1. Modeling and Simulation of Computer Integrated Manufacturing System (http://vlabs.iitkgp.ac.in/cim/exp7/index.html#)
2. Remote Monitoring and Operation of a Computer Integrated Manufacturing System (http://vlabs.iitkgp.ac.in/cim/exp7/index.html#)

For completing the above assignment, any suitable simulation software like WITNESS, Vlab facility can be used

Learning Resources

Text Books:

1. Automation, Production Systems, and Automation, Production system & Computer Integrated manufacturing, M. P. Groover Person India, 2007 2nd edition
2. Principles of Computer Integrated Manufacturing, S. Kant Vajpayee, Prentice Hall India

Reference Books:

1. Chang, T.C. and Wysk, R.A., 1997. Computer-aided manufacturing. Prentice Hall PTR.
2. Xu, X., 2009. Integrating Advanced Computer-Aided Design, Manufacturing, and Numerical Control.
Information Science Reference.
3. Weatherall, A., 2013. Computer integrated manufacturing: from fundamentals to implementation.
Butterworth-Heinemann.
4. Nanua Singh, Systems Approach to Computer Integrated Design and Manufacturing, John Wiley Publications.
5. Harrington J, Computer Integrated Manufacturing Krieger Publications 1979.
6. Zeid, CAD/CAM, Tata McGraw Hill.
7. Jha, N.K. "Handbook of Flexible Manufacturing Systems ", Academic Press Inc., 1991

MOOC / NPTEL/ YouTube Links: -

1. https://youtube.com/playlist?list=PLFW6lRTa1g808_CfYhZKdv2eXplAQiAwS
2. https://nptel.ac.in/courses/112104289
3. https://onlinecourses.nptel.ac.in/noc22_me10/preview
4. https://archive.nptel.ac.in/courses/112/104/112104289/
5. https://archive.nptel.ac.in/noc/courses/noc20/SEM1/noc20-me44/
6. http://vlabs.iitkgp.ac.in/cim/#

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PCC352-MEC: Refrigeration & Air-conditioning

Teaching Scheme		Credit	Examination Scheme	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End Sem**	**70 Marks**

Prerequisite Courses, if any:

- Fluid Mechanics; Engineering Thermodynamics; Applied Thermodynamics, Engineering Mathematics.

Course Objectives:

1. To UNDERSTAND the working principles and performance analysis of refrigeration and air conditioning systems.
2. To ANALYZE advanced refrigeration cycles and multi-pressure systems used in industry.
3. To STUDY components, controls, and modern refrigeration technologies.
4. To DEVELOP skills in psychrometric analysis and cooling load estimation for HVAC design.
5. To UNDERSTAND air distribution systems and modern HVAC technologies used in buildings and industries

Course Outcomes:

After successful completion of the course, students will be able to:

CO1: ANALYZE performance of vapour compression and vapour absorption refrigeration systems.

CO2: EVALUATE and design multi-pressure and cascade refrigeration systems.

CO3: SELECT and ANALYZE refrigeration system components and advanced refrigeration technologies.

CO4: PERFORM psychrometric analysis and estimate cooling loads for air conditioning applications.

CO5: DESIGN ventilation systems, duct layouts, and evaluate modern HVAC systems.

Course Contents

Unit I	Vapour Refrigeration Systems	(08 Hours)

Vapour compression systems: Working of simple vapour compression system, representation of vapour compression cycle (VCC) on T-s and P-h diagram, COP (Coefficient of Performance), EER (Energy Efficiency Ratio), SEER (Seasonal Energy Efficiency Ratio), IPLV (Integrated Part Load Value), NPLV (Seasonal Energy Efficiency Ratio), effect of operating parameters on performance of VCC, actual VCC. **(Numerical on vapour compression cycle).**

Vapour absorption systems: Introduction, Working of simple vapour absorption system (VAS), desirable properties of binary mixture (aqua-ammonia), performance evaluation of simple VAS **(Simple numerical treatment),** actual VAS, Lithium bromide–water absorption system, applications of VAS, comparison between VCC and VAC.

Real World Assignment

1. Study energy consumption and cooling capacity of a domestic refrigerator and estimate its COP using nameplate data.
2. P-h Diagram Simulation (Excel/MATLAB)- Develop a tool to plot cycle and calculate COP under varying conditions.

Exemplar / Practical Applications

1. Household refrigerators

2. Supermarket refrigeration
3. Industrial refrigeration plants
4. Solar absorption chillers

Unit II	Multi Pressure Refrigeration Systems	(07 Hours)

Multistage or Compound Systems: Need of multi staging, two stage compression with flash gas removal, flash intercooler and complete multistage compression system.

Multi Evaporator Systems: Single compressor-individual expansion valve, Single compressor multiple expansion valve, Individual compressor-multiple expansion valve, Individual compressor with compound compression and flash inter cooling. (Limited to two evaporators). Ammonia-CO_2 cascade cycle. (Only theoretical approach). **(Numerical on Multi Evaporator Systems).**

Real World Assignment

1. Design a two-stage refrigeration system for low-temperature applications and estimate COP.
2. Perform a case study on ammonia–CO_2 cascade systems used in industrial refrigeration.
3. Analyze performance of a multi-evaporator refrigeration system used in supermarkets

Exemplar / Practical Applications

1. Industrial freezing systems
2. Supermarket refrigeration (multi-evaporator systems)
3. Pharmaceutical cold storage
4. LNG and cryogenic applications

Unit III	Refrigeration System Components.	(08 Hours)

Major components of refrigeration systems: Compressors: reciprocating, rotary, screw, and centrifugal compressors. Characteristics and performance comparison.

Condensers: Air-cooled, water-cooled, and evaporative condensers.

Evaporators: flooded type, dry expansion type, and plate evaporators.

Expansion devices: thermostatic expansion valves, capillary tubes, electronic expansion valves. **Safety and control devices:** LP/HP cut-off controls, frost control, oil pressure failure control, motor overload protection, temperature control devices.

Real World Assignment

1. Select appropriate compressor type for a given refrigeration load based on performance criteria.
2. Design a basic refrigeration system by selecting condenser, evaporator, and expansion device

Exemplar / Practical Applications

1. HVAC chillers in commercial buildings
2. Industrial refrigeration plants
3. Heat pumps for water heating

Unit IV	Applied Psychrometry and Cooling Load Estimation	(08 Hours)

Applied Psychrometry : Psychrometric properties of moist air: dry bulb temperature, wet bulb temperature, dew point temperature, relative humidity, humidity ratio, enthalpy. Psychrometric chart and its use. Psychrometric processes

Concepts of Apparatus Dew Point (ADP), Bypass Factor (BPF). Sensible Heat Factor (SHF), Room Sensible Heat Factor (RSHF), Grand Sensible Heat Factor (GSHF), Effective Sensible Heat Factor (ESHF). **(Numerical on Applied Psychrometry).**

Cooling load estimation:

- Internal heat gains (people, lights, equipment)
- Solar heat gain through building envelope
- Ventilation and infiltration loads

Methods of cooling load calculation including CLTD/CLF method.

Thermal comfort: human comfort parameters, comfort charts, factors affecting comfort.

Indoor Air Quality (IAQ): indoor contaminants and methods to improve IAQ. Outdoor design conditions and weather data in HVAC design.

Real World Assignment

1. Calculate cooling load of a classroom/office using CLTD method considering all heat gains.
2. Plot and analyze air conditioning processes on a psychrometric chart for given conditions.
3. Evaluate indoor air quality of a space and suggest improvements based on standards.

Exemplar / Practical Applications

1. HVAC design for offices, shopping malls, hospitals
2. Clean room air conditioning
3. Thermal comfort in buildings
4. Data centre cooling systems

Unit V	Ventilation, Air Distribution and Modern HVAC Systems	(08 Hours)

Ventilation: Introduction to Ventilation and infiltration in buildings. Natural ventilation and mechanical ventilation.

Air distribution systems and duct design.

Duct design considerations including: Duct layout and materials, Pressure losses in ducts, Friction losses in ducts, Equivalent diameter for rectangular ducts (**Numerical on Duct design)**

Methods of duct design: Equal friction method; Static regain method; Velocity reduction method

Air distribution components including filters, diffusers, grills, dampers, and fan coil units. Fans used in HVAC systems and fan laws.

Modern HVAC systems: VRF (Variable Refrigerant Flow), VAV (Variable Air Volume), Desiccant-based air conditioning, Evaporative cooling systems, Thermal energy storage systems, clean room air conditioning, Radiant cooling systems.

Real World Assignment

1. Design air duct system for a small building using equal friction method.
2. Select and analyze performance of fans using fan laws for HVAC applications.
3. Study and compare modern HVAC systems (VRF/VAV) used in commercial buildings.

Exemplar / Practical Applications

1. Central air conditioning systems in airports
2. HVAC systems in shopping malls and hospitals
3. Clean room and pharmaceutical HVAC
4. Green buildings and energy-efficient HVAC systems

Learning Resources

Text Books:

1. Arora C. P., Refrigeration and Air Conditioning, Tata McGraw-Hill
2. Manohar Prasad, Refrigeration and Air Conditioning, Willey Eastern Ltd, 1983
3. McQuiston, ― Heating Ventilating and air Conditioning: Analysis and Design‖ 6th Edition, Wiley India
4. Arora and Domkundwar, Refrigeration & Air Conditioning, Dhanpatrai & Company, New Delhi
5. Khurmi R.S. and Gupta J.K., Refrigeration and Air conditioning, Eurasia Publishing House Pvt. Ltd, New Delhi,1994.
6. Ballaney P.L., Refrigeration and Air conditioning, Khanna Publishers, New Delhi, 1992

Reference Books:

1. Dossat Ray J, Principles of refrigeration, S.I. version, Willey Eastern Ltd, 2000
2. Stockers W.F and Jones J.W., Refrigeration and Air conditioning, McGraw Hill International editions 1982.
3. Threlkeld J.L, Thermal Environmental Engineering, Prentice Hall Inc., New Delhi
4. Aanatnarayan, Basics of refrigeration and Air Conditioning, Tata McGraw Hill Publications
5. Roger Legg, Air Conditioning System Design, Commissioning and Maintenance
6. ASHRAE & ISHRAE handbook

MOOC / NPTEL/ YouTube Links: -

1. **https://nptel.ac.in/courses/112107208**

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PCC353-MEC: Transmission System Design

Teaching Scheme		Credit	Examination Scheme	
Theory	4 Hours/Week	4	CCE	30 Marks
Practical	NA		End Sem	70 Marks

Prerequisite Courses, if any:

- Classification of Gears, Gear Terminology, Terminology of Helical gear, Virtual number of teeth. Classification, selection and application of Belt, chain and rope drives.

Course Objectives:

1. **UNDERSTAND** the fundamentals and philosophy of elements of transmission system.
2. **SELECT** different types of gears and bearings for specific applications.
3. **DESIGN** different types of gears for transmission systems.
4. **DESIGN** and **ANALYZE** clutches and brakes for transmission systems**.**
5. **DEVELOP** an attitude of team work, critical thinking, communication, planning and scheduling through design projects.

Course Outcomes:

After successful completion of the course, learner will be able to: On completion of the course, learner will be able to

CO. 1 **APPLY** the principle of Spur & Helical gear design for industrial application.

CO2. **DESIGN** Bevel & Worm gear considering design parameters as per design standards.

CO3.**SELECT** Rolling and Sliding Contact Bearings from manufacturer's catalogue for a typical application considering suitable design parameters.

CO4. **DESIGN** and **ANALYZE** various types of Clutches, Brakes, used in automobile.

CO5.**ELABORATE** various modes of operation, degree of hybridization in hybrid electric vehicles.

Course Contents

Unit I	Spur and Helical Gears	(07 Hours)

Introduction to gears: Material selection for gears, Modes of gear tooth failure, Gear Lubrication Methods.

Spur Gears: Number of teeth and face width, Force analysis, Beam strength (Lewis) equation, Velocity factor, Service factor, Load concentration factor, Effective load on gear, Wear strength (Buckingham's) equation, Estimation of module based on beam and wear strength, Estimation of dynamic tooth load by velocity factor and Buckingham's equation. AGMA (American Gear Manufacturing Association) approach of Gear design (Only mathematical relations, no numerical)

Helical Gears: Force analysis of Helical Gear, Beam Strength of Helical Gear, Wear strength and estimation of effective load based on Velocity factor (Barth factor) and Buckingham's equation. (No numerical on force analysis of helical)

Real World Assignment

1. Design of Helical Gears for High-Speed Rotary Equipment.
2. Design Parameters of Spur Gears for Industrial Conveyor Systems.
3. Comparison of Spur and Helical Gears in Industrial Power Transmission.
4. Analysis of Spur Gears in a Car Transmission System.

Exemplar / Practical Applications

Automobile Gearbox, Machine tool gearbox**.**

Unit II	Bevel and Worm Gear	(07 Hours)

Bevel Gears: Types of Bevel gears, Terminology, Virtual number of teeth, and force analysis of Straight Bevel
Gear. Design of Straight Bevel Gear based on Beam Strength, Wear strength and estimation of effective load based on Velocity factor (Barth factor) and Buckingham's equation. (Simple numerical to be taken no design calculations) **Worm Gears:** Worm and worm gear terminology and proportions of worm and worm gears, Force analysis of worm gear drives, Friction in Worm gears, efficiency of worm gears, Worm and worm gear material, Strength and wear ratings of worm gears (Bending stress factor, speed factor, surface stress factor, zone factor) IS 1443-1974, Thermal consideration in worm gear drive. (Simple numerical to be taken no design calculations)

Real World Assignment

1 Differential Gear Analysis with Straight Bevel Gears.
2 Elevator / Lift Gear System Study to determine if the gear pair is Self-locking or Overhauling.
3 Conveyor Speed Reduction System to decide worm gears are preferred for high reduction ratios.

Exemplar / Practical Applications

Automotive Differential gearbox, Hand-operated Drills, Elevators and lifts, Steering mechanisms, Gate opening systems.

Unit III	Sliding and Rolling Contact Bearing	(08 Hours)

Sliding contact bearing (Theoretical treatment only): Introduction to sliding contact bearing, classification, Reynolds's equation (2D), Petroff's equations, Sommerfeld number, Parameters of bearing design.

Rolling Contact Bearings: Types of rolling contact Bearings and its selection, Static and dynamic load carrying capacities, Stribeck's Equation, Equivalent bearing load, Load-life relationship, Selection of bearing life, Selection of rolling contact bearings from manufacturer's catalogue, Design for cyclic loads, Types of failure in rolling contact bearings - causes and remedies. (Simple Numerical treatment)

Real World Assignment

1. Select bearing for motorcycle wheel hub
2. Select a bearing for car wheel hub.
3. Select a bearing for electric motor

Exemplars

Automobile (Engine, wheel) bearings, Pumps, motors, Fans.

Unit IV	Design of Clutches and Brakes	(08 Hours)

Clutches: Introduction, Types of clutches, Material, Positive clutches, friction clutches, single plate, multiple plate, Cone clutch, and centrifugal clutches, Application of friction clutches automotive and industrial machinery sector. (Only Theoretical Treatment)

Brakes: Introduction, Types of brakes, Material, Design of band brake, external and internal shoe breaks internal expanding shoe brakes, design of disc brakes. Application of brakes in automotive and industrial machinery sector. (Only Theoretical Treatment)

Real World Assignment

1. Comparative Study of Automotive Clutches
2. Industrial Application of Friction Clutches
3. Design Study of Brakes for Automotive Vehicles
4. Industrial Braking Systems – Applications and Selection

Exemplar / Practical Applications:

Single plate and Multiple plate clutch, Brakes in Automobiles.

Unit V	Transmission system in Hybrid Electric Vehicle	(08 Hours)

Introduction, Types of Hybrid Electric Vehicles: Basic Classification, Basic Modes of Operation, Other Derivatives,
Degree of Hybridization. Power Split Devices (PSD): Simple and EM compound PSD, HEV Component Characteristics: The IC Engine, Electric Machines, Battery, HEV Performance Analysis: Series HEV, Parallel HEV, HEV Component Sizing: General Considerations, Sizing for Performance, Optimum Sizing, Power Management: Control Potential, Control.

Real World Assignment

1 Performance comparison of HEV vs IC engine vehicle
2 HEV component sizing exercise
3 Mode of operation mapping of existing HEV

Exemplar / Practical Applications

City buses and commercial cars, Military applications like Humvees

Learning Resources

Text Books:

1. Shigley J.E. and Mischke C.R., Mechanical Engineering Design, McGraw Hill Publication Co. ltd.
2. Spotts M.F. and Shoup T.E., Design of Machine Elements, Prentice Hall International.
3. Bhandari V.B, Design of Machine Elements, Tata McGraw Hill Publication Co. Ltd.
4. Juvinal R.C, Fundamentals of Machine Components Design, John Wiley and Sons.

Reference Books:

1. Design Data - P.S.G. College of Technology, Coimbatore.
2. Vehicle Powertrain Systems by Behrooz Mashadi, David Crolla. A John Wiley & Sons, Ltd.
3. Automobiles–Power trains and Automobiles–Dynamics by Crolla, David, A John Wiley &Sons, Ltd.
4. Automotive Engineering Powertrain, Chassis System and Vehicle Body by David A Crolla, Elsevier B H New York, London, Oxford.
5. lack P.H. and O. Eugene Adams, Machine Design, McGraw Hill Book Co. Inc.
6. Willium C. Orthwein, Machine Components Design, West Publishing Co. and Jaico Publications House.
7. P. Kannaiah, Design of Transmission systems‖, SCIETCH Publications Pvt Ltd.
8. C.S. Sharma and Kamlesh Purohit, Design of Machine Elements, PHI Learning Pvt. Ltd.
9. D.K. Aggarwal& P.C. Sharma, Machine Design, S.K Kataria and Sons.
10. P. C. Gope, Machine Design: Fundamentals and Applications, PHI Learning Pvt. Ltd.
11. Bhandari, V. B. Machine Design data book, Tata McGraw Hill Publication Co. Ltd.
12. K. Mahadevan, K. Balveera Reddy, Design Data Handbook for Mechanical Engineers, CBS Publishers.

MOOC / NPTEL/ YouTube Links: -

https://www.youtube.com/watch?v=b42_IO87X4s https://www.youtube.com/watch?v=vTZ4Gah3wfo
https://www.youtube.com/watch?v=ER6LC7ONCD8 https://www.youtube.com/watch?v=nMsB6Soz4Hc
https://www.youtube.com/watch?v=WOTDbCPukoM https://www.youtube.com/watch?v=fMNQglkUfhs
https://freevideolectures.com/course/2363/design-of-machine-elements

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PCC354-MEC: Thermal and Fluid Engineering Lab-II

Teaching Scheme		Credit	Examination Scheme	
Theory	NA	2	PR	50 Marks
Practical	4 Hours/Week		OR/TW	NA

Prerequisite Courses, if any:

- Physics, Engineering thermodynamic, Fluid Mechanics, Heat Transfer

Course Objectives:

1. To provide practical understanding of HVAC systems through performance evaluation of refrigeration and air conditioning systems.
2. To study and evaluate the performance of turbomachinery such as pumps and hydraulic turbines.
3. To introduce sustainability concepts including energy efficiency, green refrigerants, and renewable energy systems.
4. To develop skills in experimental measurement, data analysis, and interpretation of thermal and fluid systems.
5. To expose students to real-life industrial applications through case studies and industrial visits.

Course Outcomes:

After successful completion of the course, students will be able to:

CO1: CONDUCT experiments on HVAC systems and analyze performance parameters such as COP, cooling capacity, and efficiency. **(Analyze)**

CO2: EVALUATE performance characteristics of pumps and hydraulic turbines by determining head, discharge, power, and efficiency. **(Evaluate)**

CO3: APPLY thermodynamics and fluid mechanics principles to analyze and interpret experimental data of thermal and fluid systems**. (Apply)**

CO4: ASSESS energy efficiency and sustainability aspects in HVAC and turbomachinery systems, including green technologies and renewable energy applications**. (Evaluate)**

CO5: USE modern engineering tools and investigate real-life applications of thermal and fluid systems through experiments, case studies, and industrial visits**. (Analyze)**

This Lab Course Contain

1. One Simulation/Software based Experiment (Sim.)
2. Six Performance based Experiment (P)
3. Two Sustainability linked Case Study based Experiment (C)
4. Two Industrial Visit based Experiments (V)

Important information

1. Experiment No 1 to 3 are compulsory
2. Any four from Experiment No 4 to 9 (Performance)
3. Any one from Experiment No 10 & 11 (Case Studies)
4. Any one from Experiment No. 12 and 13 (Visit)

Course Contents

Experiment-1	Analysis of Vapor Compression Cycle by Cool pack software (Sim.)	(02 Hours)

Description: To simulate and analyze the vapor compression refrigeration cycle (VCC) using Cool Pack software and study the effect of operating parameters on system performance such as cooling capacity, compressor work, and coefficient of performance (COP).

Exemplars / Practical Applications:
Design and performance analysis of refrigeration and air-conditioning systems used in cold storage, food processing industries, commercial refrigeration, and building HVAC systems.

Experiment-2	**Performance Test on Vapor Compression Refrigeration System (VCRS) (P)**	**(02 Hours)**

Description: Study the working of a refrigeration system and determine its coefficient of performance (COP) under different operating conditions.

Exemplars / Practical Applications: Evaluation of refrigeration system performance used in cold storage, food processing industries, and commercial refrigeration systems.

Experiment-3	**Performance Test on Air Conditioning Test Rig (P)**	**(02 Hours)**

Description: Analyze cooling and dehumidification processes and evaluate the cooling capacity and efficiency of an air conditioning system.

Exemplars / Practical Applications: Understanding cooling and dehumidification processes used in central air-conditioning systems of hospitals, malls, and office buildings.

Experiment-4	**Performance Test on Centrifugal Pump (P)**	**(02 Hours)**

Description: Determine head, discharge, input power, and efficiency of a centrifugal pump and study its operating characteristics.

Exemplars / Practical Applications: Study of pumping systems used in water supply networks, irrigation systems, and industrial fluid transport.

Experiment-5	**Performance Test on Reciprocating Pump (P)**	**(02 Hours)**

Description: Measure theoretical discharge, actual discharge, slip, and efficiency of a reciprocating pump.

Exemplars / Practical Applications: Application in high-pressure fluid transport systems such as boiler feed pumps and hydraulic systems.

Experiment-6	**Experiment No 6: Performance Test on Pelton Wheel. (P)**	**(02 Hours)**

Description: Conduct a trial on a hydraulic turbine and determine its output power and overall efficiency.

Exemplars / Practical Applications: Understanding energy conversion used in hydroelectric power plants and renewable energy generation systems.

Experiment-7	**Performance Test on Francis Turbine. (P)**	**(02 Hours)**

Description: Study the construction and working of a Francis turbine and evaluate its performance by measuring head, discharge, power, and efficiency under different loads.

Exemplars / Practical Applications: The Francis turbine is widely used in hydroelectric power plants operating under medium head conditions. This experiment helps in understanding turbine performance, which is essential for selecting suitable turbines in power generation projects, improving energy efficiency, and designing hydraulic machines used in renewable energy applications.

Experiment-8	**Performance Test on Kaplan Turbine. (P)**	**(02 Hours)**

Description: Study the construction and working of a Kaplan turbine and evaluate its performance by measuring head, discharge, power, and efficiency under varying load conditions.

Exemplars / Practical Applications: The Kaplan turbine is commonly used in hydroelectric power plants for low head and high discharge conditions. This experiment helps in understanding turbine performance, which is important for efficient power generation, turbine selection, and design of hydraulic systems in renewable energy applications.

Experiment-9	**Determination of Impact of Jet on Vanes (P)**	**(02 Hours)**

Description: Study the effect of a water jet striking different types of vanes and determine the force developed due to change in momentum. The experiment verifies the principle of linear momentum**.**

Exemplars / Practical Applications: This concept is used in the design and analysis of hydraulic machines such as Pelton turbine, where high-velocity water jets strike buckets to produce power. It also helps in understanding fluid force interactions in nozzles, turbines, and fluid flow systems.

Experiment-10	**Case Study of Green Refrigerants and Environmental Impact in HVAC / Refrigeration System in Commercial Buildings or Cold Storage Facilities (CS)**	**(02 Hours)**

Description: Analyze the design and operation of HVAC/ Refrigeration systems in buildings and identify energy-saving opportunities.

Exemplars / Practical Applications:
Analysis of HVAC systems used in green buildings and energy-efficient infrastructure.

Experiment-11	**Case Study of Pumping System in Building Water Supply / Industrial Application (CS)**	**(02 Hours)**

Description:
1. Evaluate pump selection and operation in building water supply systems for efficient fluid transport.
2. Examine different refrigerants and compare their environmental impact and sustainability aspects

Exemplars / Practical Applications:
1. Evaluation of pump selection and operation in building water distribution systems and municipal pumping stations.
2. Adoption of environmentally friendly refrigerants in sustainable refrigeration and air-conditioning systems**.**

Experiment-12	**Industrial visit to Sustainable HVAC System / Green Building / Cold storage facilities (V)**	**(02 Hours)**

Description: Observe the working of centralized air-conditioning systems, chillers, cooling towers, cold storage, sustainable cooling systems and energy management systems.

Exemplars / Practical Applications: Observation of chiller plants, cooling towers, air handling units, and building management systems used for efficient cooling in large buildings. (Radiant Cooling, District Cooling)

Experiment-13	**Industrial visit to Hydropower Plant / Sustainable Turbomachinery System (V)**	**(02 Hours)**

Description: Study the operation of turbines or large pumping systems used for power generation or water distribution.

Exemplars / Practical Applications: Study of turbine operation and renewable energy generation using hydropower systems. (e.g Koyna Hydroelectric Project)

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

MDM-371 MEC: Digital Manufacturing Laboratory

Teaching Scheme		Credit	Examination Scheme	
Theory	NA	1	PR	50 Marks
Practical	2 Hours/Week		OR/TW	NA

Prerequisite Courses, if any:

- Fundamentals of measurement, Construction and operating of conventional machine tools, principles of machining and forming processes, cutting tool and machining parameters, basics of 3D printing.

Course Objectives:

After completing this course, students will be able to:

1. UNDERSTAND the principles of engineering metrology and apply modern measuring instruments for dimensional and geometrical inspection.
2. DEVELOP skills in advanced measurement systems such as optical instruments and Coordinate Measuring Machines (CMM).
3. APPLY statistical process control (SPC) techniques using software tools for quality analysis and process improvement.
4. GAIN proficiency in CNC programming and machining, including process planning and tolerance specification.
5. UNDERSTAND and UTILIZE digital and advanced manufacturing technologies such as additive manufacturing, simulation, and digital manufacturing tools. Analyze real-world manufacturing systems through simulation and industrial exposure, including concepts of smart manufacturing and digital twin.

Course Outcomes:

On completion of the course, Student will be able to

CO1: DEMONSTRATE the use of conventional and digital measuring instruments for linear and angular measurements and evaluate component dimensions.

CO2: ANALYZE and DETERMINE the geometry and dimensions of components using advanced measurement systems such as optical projectors and Coordinate Measuring Machine

CO3: APPLY statistical process control techniques by constructing and interpreting control charts using suitable software tools

CO4: DEVELOP and VALIDATE CNC part programs using G and M codes and APPLY CNC simulation tools for machining operations.

CO5: PERFORM CNC machining of components with proper process planning, tolerances, and manufacturing drawings.

CO6: APPLY Additive Manufacturing and Digital Manufacturing tools for process simulation and ANALYZE production systems including bottleneck identification, with understanding of Digital Twin and Smart Manufacturing concepts.

Course Contents

The student shall complete the following activity;

1. Study and measurement of linear and angular dimensions using conventional and digital measuring instruments such as Vernier calliper, micrometre, height gauge, dial gauge, and bevel protractor.
2. Determination of geometry and dimensions of a given composite object using an optical projector or toolmaker's microscope.
3. Determination of geometry and dimensions of a given sample by using Coordinate Measuring Machine.
4. Preparation and analysis of control charts ($\bar{X}$ and R Charts) using suitable statistical software.
5. Preparation of manual CNC part programs using G-codes and M-codes as per ISO (DIN 66025) and RS274 standards for CNC lathe/milling machines, and execution on a CNC simulator.
6. Machining of a mechanical component using CNC machines (Lathe/Mill/HMC/VMC), including preparation of manufacturing drawings with appropriate geometrical and dimensional tolerances and detailed process planning.
7. Demonstration of additive manufacturing technology, covering the complete process from modelling to printing.
8. Demonstration of the use of digital manufacturing tools for process simulation of manufacturing processes such as casting, forging, sheet metal forming, and plastic processing (using free/open-source software).
9. Simulation of a production/manufacturing system, including basic production line simulation, identification of bottlenecks, and an introduction to digital twin and smart manufacturing concepts.

   Industrial visit to a facility utilizing advanced manufacturing processes.

Note: Any eight practical shall be performed from the given list

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

MDM 372-MEC: Engineering Simulation and Analysis

Teaching Scheme		Credit	Examination Scheme	
Theory	NA	1	PR	50 Marks
Practical	2 Hours/Week		OR/TW	NA

Prerequisite Courses, if any:

- Engineering Mechanics, Solid Mechanics, Mechanical Vibration and Heat Transfer

Course Objectives:

1. To DEVELOP foundational understanding of Finite Element Analysis methodology by formulating and solving 1D bar, truss element and thermal problems computationally.
2. To UP SKILL students in applying FEA software tools for stress, deflection, and concentration analysis of structural components under various loading conditions.
3. To EQUIP students with the ability to perform dynamic analysis including modal analysis to determine natural frequencies and mode shapes of mechanical components.
4. To PROVIDE exposure to advanced FEA techniques such as sub modeling and coupled analysis.
5. To ENHANCE practical skills in interpreting simulation results and validating them with theoretical concepts.

Course Outcomes:

After successful completion of the course, learner will be able to:

CO1: ANALYZE stress analysis problems of 1D bar and truss elements using FEA software.
CO2: EVALUATE stress concentration factors, stresses, and deflections in machine components with geometric discontinuities and complex 3D geometries using FEA software.
CO3:INTERPRET results from modal analysis—understanding natural frequencies, mode shapes, and their physical significance—to make informed vibration-related design decisions.
CO4:IMPLEMENT submodeling techniques to perform refined localized analysis of critical regions within a mechanical system and justify the choice of boundary conditions.
CO5: ANALYZE steady-state heat transfer analysis through composite structures and coupled thermal structural Analysis to assess thermomechanical behavior of engineering components.

Course Contents

Experiment-1	Stress analysis of 1D bar element	(02 Hours)

Description: Performe stress analysis on a one-dimensional bar element to determine axial stress, strain, and displacement under applied loads using FEA software. Students will interpret the results to understand material behavior. Students will interpret the results to understand stress distribution and validate structural response calculations

Exemplars / Practical Applications

Analysis of axial stress and deformation in tie rods, Structural assessment of elevator cables and suspension components, Design verification of connecting rods etc.

Experiment-2	Structural analysis of a 1D truss element	(02 Hours)

Description: Analyzing a 1D truss element using FEA software to determine nodaand force reaction under given loading conditions. The results are used to understaverify the structural response of the truss member.		
Exemplars / Practical Applications: Analysis of bridge truss members, Design verification of roof trusses used in industrial assessment of transmission tower members subjected to wind and cable loads etc		
Experiment-3	**Determination of static stress concentration factor calculation for a plate with center hole subjected to axial loading in tension using FEA software**	**(02 Hours)**
Description: Analyze flat plate with a central hole under axial tensile loading and examine how stresses are distributed around the hole. The static stress concentration factor is determined by comparing the peak stress at the hole edge with the average applied stress in the plate. Exemplars / Practical Applications: Perforated structural plates and panels used in aerospace and automotive components, stress concentration effects in machine parts such as brackets, gusset plates, and mounting plates with holes etc**.**		
Experiment-4	**Stress and deflection analysis of any machine component consisting of 3-D elements using FEA software.**	**(02 Hours)**
Analyzing a three-dimensional machine component using FEA software to determine stress distribution and deflection under applied loads. The results are used to evaluate structural performance and identify critical regions of stress and deformation.		
Exemplars / Practical Applications: Gear tooth to assess contact stresses, Structural analysis of a bracket or mounting frame used in machinery, Analysis of a crankshaft to determine stress concentration and deflection under engine loading conditions. Etc.		
Experiment-5	**Modal analysis of any machine component using FEA software.**	**(02 Hours)**
Perform modal analysis of a machine component using FEA software to determine its natural frequencies and corresponding mode shapes. The results are used to understand the dynamic behavior of the component and identify conditions that may lead to resonance.		
Exemplars / Practical Applications Study of a turbine blade to determine mode shapes and prevent failure due to vibrational stresses, Modal Analysis of an Aero plane wing, Analysis of a bracket or support frame to ensure it does not resonate under operational vibrations etc.		
Experiment-6	**Analysis of mechanical system using submodeling approach**	**(02 Hours)**
Analyzing a mechanical system using the submodeling approach in FEA, where a global model is first solved to obtain overall response and boundary conditions. A detailed local model is then created for a critical region to evaluate stresses and deformations with higher accuracy		
Exemplars / Practical Applications Bicycle frame analysis, gear tooth contact region, bracket connected to a large machine assembly,local deflection and stress evaluation in a turbine blade root region etc.		
Experiment-7	**Steady state heat transfer through composite wall using FEA software**	**(02 Hours)**

Using FEA software to analyze steady-state heat transfer through a composite wall made of different materials with varying thermal properties. The temperature distribution and heat flow are determined to understand thermal performance under constant boundary conditions.

Exemplars / Practical Applications

Thermal behavior in furnace or boiler walls with refractory and metal layers, Analysis of heat transfer through building walls made of brick, insulation, and concrete layers etc

Experiment-8	**Coupled Thermal-Structural Analysis using FEA software**	**(02 Hours)**

Performing coupled thermal-structural analysis using FEA software to study the interaction between temperature distribution and resulting mechanical stresses in a component. The results help evaluate how thermal loads influence deformation and structural integrity under operating conditions etc

Exemplars / Practical Applications

Engine components like cylinder heads under combined heat and mechanical loading, Turbine blades to study thermal stresses and deformation due to high-temperature gas flow and brake discs to assess thermal expansion and stress during repeated braking cycles etc

Learning Resources

Text Books:

1. Gokhale N. S., Deshpande S. S., Bedekar S. V. and Thite A. N., Practical Finite Element Analysis,
Finite to Infinite, Pune, 1st Edition, 2008.
2. S. S. Bhavikatti, Finite Element Analysis, New Age International Publishers, Third Edition, 2015.
3. Chandrupatla T. R. and Belegunda A. D., Introduction to Finite Elements in Engineering, Prentice Hall
India, 2002.
4. G Lakshmi Narasaiah, Finite Element Analysis, BS Publications / BSP Books, 2nd edition, 2020.
5. J. N. Reddy, An Introduction to the Finite Element Method, Mcgraw Hill Series in Mechanical, 2005.
6. P. Seshu, Text book of Finite Element Analysis, PHI Learning Private Limited, New Delhi, 10th Printing, 2012.

Reference Books:

1. Bathe K. J., Finite Element Procedures Prentice, Hall of India (P) Ltd., New Delhi.
2. R. D. Cook, et al., Concepts and Applications of Finite Element Analysis. Wiley, India
3. David V. Hutton, Fundamental of Finite Element Analysis, Tata McGraw-Hill
4. S. Moaveni, Finite element analysis, theory and application with Ansys, Prentice Hall
5. O.C. Zienkiewicz, The Finite Element Method: Its Basis and Fundamentals, Sixth Edition, Elsevier
Butterworth-Heinemann, 2005.

MOOC / NPTEL/ YouTube Links: -

1. NPTEL – FEM Course by Prof. C.S. Upadhyay, IIT Kanpur
2. ANSYS Learning Hub — ansys.com/training (free student access)
3. SimScale Community — cloud-based FEA practice (free tier available)

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

VSE 381: Solar Technology and Maintenance

Teaching Scheme		Credit	Examination Scheme	
Theory	**NA**	**1**	**CCE**	**50 Marks**
Practical	**2 Hours/Week**		**PR**	**NA**

Prerequisite Courses, if any:

- Basic knowledge of Physics (especially topics like electricity, magnetism semiconductors, light/energy concepts, Basic Electrical Engineering or Basic Electronics, Engineering Mechanics. Heat and energy concepts

Course Objectives:

1.APPLY Safely install, wire, and commission basic solar PV systems while measuring key performance parameters.

2.ANALYZE Break down the impact of environmental and operational factors on solar system efficiency
and diagnose common faults.

3.EVALUATE Judge the effectiveness of maintenance and troubleshooting procedures for solar PV components and systems.

4. DEVELOP simple practical solutions or documentation for improving solar system performance in mini-projects.

Course Outcomes:

After successful completion of the course, learner will be able to:

CO1: APPLY safe installation, wiring, commissioning, and performance measurement of basic solar PV systems.

CO2: ANALYZE the impact of environmental/operational factors on solar PV efficiency and diagnose common faults.

CO3: EVALUATE the effectiveness of maintenance and troubleshooting procedures for solar PV components and systems.

CO4: CREATE simple practical solutions or documentation for improving solar system performance via mini-projects.

Course Contents

Experiment-1	**Measurement of solar irradiance using pyrometer/lux meter at different times/angles.**	**(02 Hours)**

Title: Measurement of solar irradiance using pyrometer/lux meter at different times/angles.

Real World Assignment

1. Survey irradiance on your college rooftop for one day.
2. Calculate daily energy generation for a 100W panel and suggest best installation time/angle for maximum output.

Experiment-2	**Plot I-V and P-V characteristics of solar PV modules under varying light & temperature.**	**(02 Hours)**

Title : Plot I-V and P-V characteristics of solar PV modules under varying light & temperature.

Real-World Assignment:
Simulate cloudy/rainy day conditions. Calculate module efficiency and estimate annual energy loss in Pune climate.

Experiment-3	**Survey and Comparative Analysis of Solar PV Installation Systems: Grid-Tied, Hybrid, and Off-Grid Configurations.**	**(02 Hours)**

Title : Survey and Comparative Analysis of Solar PV Installation Systems: Grid-Tied, Hybrid, and Off-Grid Configurations.

Real-World Assignment: Survey 2–3 real solar installations (e.g., college rooftop, nearby home/business, or online/virtual

Experiment-4	**Series and parallel connection of PV modules, observe mismatch issues.**	**(02 Hours)**

Title : Series and parallel connection of PV modules, observe mismatch issues.

Real-World Assignment: Design a small array for 12V/24V system (e.g., for laptop charging or lab fan). Calculate total power and suggest fuse/ diode protection for mismatch in a multi-panel rooftop installation.

Experiment-5	**Installation and wiring of standalone solar PV system (PV → Charge controller → Battery → Load/Inverter)**	**(02 Hours)**

Title: Installation and wiring of standalone solar PV system (PV → Charge controller → Battery → Load/Inverter)

Real-World Assignment: Prepare a complete wiring diagram and BOM for a 100W system to power a college water cooler or hostel room. Include safety earthing and cable sizing as per real IEC standards.

Experiment-6	**Preventive maintenance: Cleaning, visual inspection, corrosion/loose connection check.**	**(02 Hours)**

Preventive maintenance: Cleaning, visual inspection, corrosion/loose connection check.

Real-World Assignment:
Title: Inspect any existing solar panel in college/hostel. Prepare a 6-month maintenance schedule with cost estimation (dust cleaning, tightening)

Experiment-7	**Grid-Related Maintenance Checks for Grid-Tied Solar PV Systems: Inverter Health, Performance Monitoring, and Fault Diagnosis.**	**(02 Hours)**

Title: Grid-Related Maintenance Checks for Grid-Tied Solar PV Systems: Inverter Health, Performance Monitoring, and Fault Diagnosis

Real-World Assignment:
Survey a real grid-tied installation, Prepare a maintenance schedule: Monthly inverter check, quarterly visual, annual professional inspection.

Experiment-8	**Mounting structure assembly: Rooftop/ground mount, tilt adjustment, stability check**	**(02 Hours)**

Title: Mounting structure assembly: Rooftop/ground mount, tilt adjustment, stability check

Real-World Assignment: Design a simple mounting frame for windy Pune conditions. Calculate wind load and suggest material/cost for a 5kW residential installation.

Experiment-9	**IoT-Based Real-Time Solar PV System Monitoring and Performance Dashboard.**	**(02 Hours)**

Title: IoT-Based Real-Time Solar PV System Monitoring and Performance Dashboard.

Experiment-10	**Industrial Visit to Solar Energy Facility in Pune Region: Hands-On Learning of Solar PV System Operations and Maintenance**	**(02 Hours)**

Title: Industrial Visit to Solar Energy Facility in Pune Region: Hands-On Learning of Solar PV System Operations and Maintenance

Important Note :

1. Experiment no.1, 2 and 10 are compulsory.
2. Perform any 2 Experiments from 3 to 5 and
3. Perform any 3 Experiments from 6 to 9

Learning Resources

Text Books:

1. S.P. Sukhatme, Solar Energy
2. C.S. Solanki, Solar Photovoltaics
3. D.P. Kothari et al., Renewable Energy Sources
4. G.D. Rai, Non-Conventional Energy Sources
5. H.P. Garg, Solar Energy Utilization

Reference Books:

1. Solar Photovoltaic Technology and Systems: A Manual for Technicians, Trainers and
2. Engineers Author: Chetan Singh Solanki.
3. Solar PV System: Design, Installation, Operation and Maintenance Authors: L. Ashok Kumar and K. Mohana Sundaram.
4. Solar Engineering of Thermal Processes, Photovoltaics and Wind (5th Edition) Authors: John A. Duffie, William A. Beckman (updated with Nathan Blair).
5. Principles of Solar Engineering (3rd Edition) Authors: D. Yogi Goswami, Frank Kreith, Jan F. Kreider

MOOC / NPTEL/ YouTube Links: -

1. Solar Photovoltaics: Fundamentals, Technology and Applica

   https://onlinecourses.nptel.ac.in/noc24_ph26/preview?utm_so

2. Skill Cat or Other Free Solar Training (Installation Focus).

   https://www.skillcatapp.com/solar-installation-training

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PEC 361A-MEC: Industrial Tribology

Teaching Scheme		Credit	Examination Scheme	
Theory	3 Hours/Week	3	CCE	30 Marks
Practical	NA		End Sem	70 Marks

Prerequisite Courses, if any:

- Physics, Chemistry, Mathematics, Fluid Mechanics, Theory of Machine and Machine Design

Course Objectives:

1. To PROVIDE the knowledge and importance of Tribology in Design, friction, wear and lubrication aspects of machine components and to select proper grade lubricant for specific application.
2. To UNDERSTAND the principles of lubrication, lubrication regimes, hydrostatics and hydrodynamic lubrication.
3. To IMPART knowledge and principles of Elasto-hydrodynamic lubrication and Gas lubrication.
4. To UNDERSTAND the IoT applications in tribology.

Course Outcomes:

After successful completion of the course, learner will be able to:

CO. 1: APPLY the fundamental principles of tribology, concept of friction, wear, lubrication and selection of lubricants.

CO. 2 : ANALYZE the performance of hydrostatic and squeeze film lubrication, oil flow requirement, pressure distribution for step bearing.

CO. 3: APPLY the hydrodynamic lubrication theory to calculate pressure distribution and load capacity in journal and trust bearing.

CO. 4 : EXPLAIN the fundamental concepts of Elasto-hydrodynamic lubrication and Gas lubrication, identify their applications.

CO. 5: ANALYZE tribological behavior of nanoscale contacts, tyre road interactions, IoT based condition monitoring and biolubricants based systems

Course Contents

Unit I	Introduction to Tribology	(07 Hours)

Importance of Tribology in Design, Tribology in Industry, Economic Considerations, Lubrication Definition, Lubricant properties, Viscosity, its measurements- Numerical, basic modes of lubrication, types of lubricants, Standard Grades of lubricants, selection of lubricants, commonly used lubricants and Hazards, Recycling of used oil, Disposal of used oil, bearing materials, bearing construction, oil seals and gaskets.

Introduction to friction & wear, Laws of friction, kinds of friction, causes of friction, area of contact, friction measurement, theories of friction. Types of wear, various factors affecting wear, measurement of wear, wear between solids and flowing liquids, theories of wear

Real World Assignment

1 Selection of lubricants for different applications.

Exemplars:

Tribology in Industry, lubricants, Laws of friction, measurement of wear.

Unit II	Hydrostatic Lubrication	(07 Hours)

Introduction to hydrostatic lubrication, hydrostatic step bearing, load carrying capacity and oil flow through the hydrostatic step bearing- Numerical. Hydrostatic squeeze film : basic concept, circular and rectangular plate approaching a plane Numerical

Real World Assignment

1 Investigating effect lubricant flow rate on a pressure.
2 Identification of common faults in hydrostatic lubrication system.
3 Survey of components in hydrostatic lubrication system.
4 Effect of loading on pressure and lubricant film thickness.

Exemplar / Practical Applications

Milling Machine, Boring Machine, grinding Machine, Radar Tracking machines, Power station turbines.

Unit III	Hydrodynamic Lubrication	(08 Hours)

Theory of hydrodynamic lubrication, mechanism of pressure development in an oil film. Two dimensional Reynolds equation, Petroff's equation, pressure distribution in journal bearings - long & short, Load Carrying capacity, Somerfield number and its importance- Numerical. Introduction to Hydrodynamic Thrust Bearing

Real World Assignment

1 Explain the mechanism of pressure development in an oil film.
2 To Study the failure of journal bearing due to lubrication break down.
3 Define load carrying capacity of a journal bearing & Solve one numerical.

Exemplar / Practical Applications

Automobile industry=Sommerfeld number, Hydraulic turbines=load carrying capacity, Steam turbines: hydrodynamic thrust bearings.

Unit IV	Elasto-hydrodynamic lubrication and Gas Lubrication	(07 Hours)

Elasto-hydrodynamic lubrication: Basic concept, Hertzian contact theory, Elasto-hydrodynamic lubrication EHL regimes in: Line contact (e.g., gears) and Point contact (e.g., rolling bearings), different regimes in EHL contacts. Pressure-viscosity relationship. Stick-slip phenomenon.

Gas lubrication: Introduction, merits and demerits, applications, Properties of gases as lubricants, and comparison with liquid lubrication, externally pressurized gas bearings, porous gas bearings, and Dynamic characteristics of gas lubricated bearing, Rarefied gas effects (Knudsen number), Slip flow conditions.

Real World Assignment

1. Study lubrication behavior in gear tooth contacts under high load to understand lubrication in automotive power transmission systems.
2. Analyze EHL in ball and roller bearings to understand bearing life and lubrication design.
3. Study gas lubrication in precision engineering systems to understand frictionless high-speed systems.
4. Explore gas lubrication at micro-scale in Micro Electro Mechanical Systems (MEMS) to understand advanced and emerging tribology systems.
   To analyze lubrication challenges in wind turbine gearboxes and propose solutions using EHL principles and advanced lubrication strategies.

Exemplar / Practical Applications

EHL in Automotive Gear Systems, EHL in Rolling Element Bearings, Gas Lubrication in High-Speed Air Bearings, Precision instruments, Gas Lubrication in MEMS (Micro-Electro-Mechanical Systems) & Micro Devices.

Unit V	Advances in Tribology	(07 Hours)

Introduction to advanced tribology, IoT applications in tribology, Artificial intelligence in tribology, Surface topography and its tribological significance, Surface measurement techniques, Biolubricants and green tribology, Nanotribology and nano-enabled lubrication, Tyre & Road contacts, Industrial relevance and future trends.

Real World Assignment

1. Evaluate tribological practices in an industry and give suggestions for efficiency improvement.
2. Analyze a real component failure due to wear, friction, or lubrication issues and conduct root cause analysis.
3. Select vegetable oil-based lubricant and compare it with mineral oil in terms of viscosity, wear, friction.
4. Apply AI techniques for predicting wear or lubrication performance.

Exemplar / Practical Applications

Bearing wear analysis, Smart lubrication, Wear prediction using AI, Roughness vs wear correlation, Eco-friendly lubrication, Use of Nano-additives, Braking & skid behavior.

Learning Resources

Text Books:

1 Basu S.K., Sengupta S. N. and Ahuja B.B. “Fundamentals of Tribology” PHI Learning, Ltd. India.

2 Majumdar B. C. "Introduction to Tribology and Bearings", S. Chand and Company Ltd., New Delhi.

Reference Books:

1 Bharat Bhushan, “Principles and Applications of Tribology”, John Wiley and Sons.

2. Sahu P., “Engineering Tribology”, PHI Learning, Ltd. India

3. Fuller D.D. "Theory and Practice of Lubrication for Engineers". John Wiley and Sons.

4. Neale M. J. "Tribology hand Book", Butterworths. London.

5. Orlov P., "Fundamentals of Machine Design", Vol. IV, MIR Publication.

6. Cameron A. "Basic Lubrication Theory", Wiley Eastern Ltd.

7. 'Hailing J., "Principles of Tribology", McMillan Press Ltd., 1975.

8. Ghosh M.K., Mujumdar B.C. and Sarangi M., “Theory of lubrication”, Tata McGraw Hill Education Pvt. Ltd., New Delhi.

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)
PEC 361B-MEC: Design of Heat Transfer Equipment

Teaching Scheme		Credit	Examination Scheme	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End Sem**	**70 Marks**

Prerequisite Courses, if any:

Fluid Mechanics; Engineering Thermodynamics; Heat Transfer

Course Objectives:

1. To UNDERSTAND the classification, working principles, and design methodology of heat exchangers.
2. To ANALYZE the effects of pressure, drop and fouling on heat exchanger performance.
3. To DESIGN and EVALUATE different types of heat exchangers used in industrial applications.
4. To STUDY direct contact heat exchangers such as cooling towers and their design aspects.
5. To EXPLORE modern cooling techniques including heat pipes for electronics and thermal systems.

Course Outcomes:

After successful completion of the course, students will be able to:

CO1: EXPLAIN classification, working principles, and design methods of heat exchangers.

CO2: DESIGN and EVALUATE double pipe and shell-and-tube heat exchangers

CO3: ANALYZE performance and design requirements of Boilers, Condensers and cooling towers.

CO4:. ANALYZE pressure drop and fouling effects on heat exchanger performance

CO5: APPLY heat pipe technology for cooling of electronic and electrical systems.

Course Contents

Unit I	Fundamentals of Heat Exchangers	(08 Hours)

Introduction and applications of Heat exchangers in (Power plants, HVAC, refrigeration, process industries),Classification of heat exchangers based on flow arrangement (parallel, counter, cross-flow), Based on construction (shell-and-tube, plate, compact), Heat transfer mechanisms (conduction, convection), Overall heat transfer coefficient, Fouling factor and its significance, Basic thermal design considerations

Real World Assignment

1. Study and classify heat exchangers used in a local industry / HVAC system / automobile radiator, and identify type, flow arrangement, and heat transfer mechanism.
2. Develop a MATLAB/Excel tool to calculate heat transfer rate using LMTD and ε–NTU methods for given inlet conditions.

Exemplar / Practical Applications

1. Automobile radiators
2. HVAC cooling and heating coils
3. Condensers and evaporators in refrigeration systems

4. Heat exchangers in chemical and process industries

Unit II	Design of Shell-and-Tube Heat Exchangers	(06 Hours)

Shell & Tube Heat Exchangers: Tube layouts for exchangers, Baffled heat exchangers, ASME and TEMA standards (basic introduction), Thermal design procedure, Mechanical design considerations (stress, thickness, pressure), Calculation of shell and tube heat exchangers, Shell-side and tube-side heat transfer coefficients , Shell side equivalent diameter (Kerns method, Bell Delaware method), Shell side pressure drop, Tube side pressure drop.

Real World Assignment

1. Conduct a case study on fouling in industrial heat exchangers (e.g., scale formation in boilers or condensers) and suggest mitigation techniques.
2. Calculate pressure drop across a tubular heat exchanger for given flow conditions using analytical relations.

Exemplar / Practical Applications

1. Fouling in power plant condensers
2. Pressure drop in oil and gas pipelines
3. Scaling in heat exchangers used in chemical industries
4. Maintenance and cleaning schedules in industrial plants

Unit III	Design of Thermal Systems	(07 Hours)

Introduction, Classification of boilers, Basic Design Considerations of Boiler, Heat Transfer & Furnace Design , Boiler performance and efficiency calculations, Brief case study on Heat Recovery systems, Types of condensers (Jet & surface), Design considerations of condensers and Cooling towers, Heat transfer analysis of Cooling Towers.

Real World Assignment

1. Design a Boiler for a given application (water–oil or air–water system) including thermal and hydraulic analysis.
2. Perform design calculations of Condenser and Cooling Towers.

Exemplar / Practical Applications

1. Boilers in refineries
2. Heat exchangers in power plants
3. Industrial oil coolers
4. Chemical processing equipment

Unit IV	Design of Specialized Heat Exchangers	(07 Hours)

Plate heat exchangers, Finned tube heat exchangers, Compact heat exchangers (automotive, aerospace applications), Air-cooled heat exchangers, Double-pipe heat exchangers, Selection criteria for heat exchangers in industries like Automotive and aerospace applications, Optimization of Heat Exchanger- Heat transfer equipment cost, relative cost, optimum design, CFD analysis basics in heat exchanger design,

Real World Assignment

1. Perform performance analysis of a Heat exchanger (based on experimental or standard data) and calculate effectiveness, range, and approach.
2. CFD analysis basics in heat exchanger design using heat balance equations.

Exemplar / Practical Applications

1. Cooling towers in thermal power plants

2. HVAC cooling systems in large buildings
3. Industrial water-cooling systems
4. Petrochemical and steel plant cooling applications

Unit V	Heat Pipes and Applications	(07 Hours)

Heat pipes : structures - applications - basic relations - performance characteristics - effects of working fluid and operating temperature, wick - selection of material - pore size (basic concepts only), Cooling of electrical and electronic components: Cooling of chips, PCBs, Computers, Logic chips etc., Electrical transformers, Panel boards, Electric motors, microchannel heat exchangers

Real World Assignment

1. Design a basic heat pipe cooling system for a laptop/CPU and estimate heat transfer capability.
2. Study and compare conventional cooling vs heat pipe-based cooling systems in electronics.

Exemplar / Practical Applications

1. Laptop and CPU cooling systems
2. Cooling of power electronics and transformers
3. Aerospace thermal control systems
4. LED and high-performance chip cooling

Learning Resources

Text Books:

1. Fundamentals of Heat Exchanger Design by Ramesh K Shah, Wiley Publication
2. Compact Heat Exchangers by Kays, V.A. and London, A.L., McGraw Hill.
3. Process Heat transfer by Donald Q Kern, McGraw Hill.

Reference Books:

1. Heat Exchanger Design Handbook by Kuppan, T, Macel Dekker, CRC Press
2. Heat Exchanger Selection, Rating and Thermal Design by Sadik, Kakac, CRC Press

MOOC / NPTEL/YouTube Links: -

1. https://nptel.ac.in/courses/112105248
2. https://nptel.ac.in/courses/103107207
3. https://nptel.ac.in/courses/103101137

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PEC 361C-MEC: Hydraulic and pneumatics

Teaching Scheme		Credit	Examination Scheme	
Theory	3 Hours/Week	3	CCE	30 Marks
Practical	NA		End Sem	70 Marks

Prerequisite Courses, if any:

- Fluid Mechanics, Manufacturing Process and Machines, Mechatronics

Course Objectives:

1. To UNDERSTAND fundamentals of fluid power systems and hydraulic pumps
2. To IDENTIFY and SELECT the proper actuator and power unit for various hydraulic power system applications
3. To UNDERSTAND the construction, working, and applications of fluid power control valves and regulation techniques
4. To STUDY working principles of various components and their industrial applications
5. To STUDY how to design fluid power systems To study low cost automation

Course Outcomes:

CO. 1 : APPLY basic fluid power principles and analyze hydraulic systems.
CO. 2 : IDENTIFY and SELECT various components for hydraulic power systems
CO. 3 : IDENTIFY various control valves and auxiliaries used in fluid power systems
CO. 4 : IDENTIFY and SELECT various components and circuits for pneumatic power systems
CO. 5 : DESIGN a system according to the requirements

Course Contents

Unit I	Fundamentals of fluid Power Systems	(08 Hours)

Introduction to Fluid Power - Definition and concept of fluid power, Comparison between hydraulics and pneumatics, Advantages, limitations, and applications of fluid power systems.
Fluid Properties and Selection- Types of hydraulic fluids, Properties: viscosity, density, specific gravity, Selection criteria for hydraulic fluids, ISO and SAE oil grading of oils
Basic Principles of Hydraulics- Pressure, force, and area relationship, Pascal's Law and applications, Basics of fluid flow, Friction and energy losses in systems
Hydraulic Pumps- Types and Working- Pumping theory - Classification of pumps, Construction & working of: Gear pump, Vane pump, Piston pump (axial & radial) , Screw pump- Performance characteristics curves, power and efficiency calculations, selection criteria of pumps.
ISO symbols used in hydraulic systems and Pneumatic system

Real World Assignment

1) Activities on Identify and study any real-life hydraulic and pneumatic system (e.g., hydraulic jack, air compressor), Compare working principles of hydraulics and pneumatics, List components and draw basic circuit using ISO symbols.
2) Activates on : Verification of Pascal's Law using hydraulic trainer kit / setup and verify relationship between pressure, force, and area
3) Activities on Visualize fluid flow and pump operation using suitable software or animations.

Exemplars / Practical Applications

1) Hydraulic jack used in automobile servicing
2) Hydraulic braking system in vehicles
3) Excavator and earthmover hydraulic systems
4) Injection molding machines (hydraulic operation)
5) Pneumatic systems in automation (pick-and-place robots)
6) Press machines used in manufacturing industries

Unit II	Hydraulic system components and Design	(07 Hours)

Linear and rotary actuators- types, construction and characteristics. Selection of actuators. Cylinder mountings, cushioning of cylinders. Maintenance of actuators.

Power units and accessories - types of power units, reservoir assembly, constructional details. Accumulators, Intensifiers, Pressure and Temperature switches /sensors, level sensors

Real World Assignment:

1) Activity on Hydraulic actuator selection for industry as per application.
2) Comparative study of linear and rotary actuators used in various earth moving equipment.
3) Suggest a proper maintenance plan for actuators, power units and accessories used in particular industry.
4) Design of simple hydraulic systems used in practice using manufacturers' catalogue and analysis using software such as Automation Studio.

Exemplars / Practical Applications

1) Hydraulic actuators are used in excavators to control the movement of the arm, bucket, and boom for digging operations.
2) Hydraulic presses used linear actuators to apply high force for shaping and forming materials in manufacturing industries.
3) Hydraulic power unit supply pressurized fluid to operate machine tools and various industrial systems efficiently.
4) Pressure sensors are used in hydraulic systems to monitor and control system pressure for safe operation.
5) Temperature and level sensors help in monitoring fluid condition and maintaining proper fluid

Unit III	Fluid Power Control Valves and Regulation Techniques	(07 Hours)

Control Components: Direction Control Valves (DCV), Flow Control Valves (FCV) and Pressure Control Valves (PCV) – Types (2/2, 3/2, 4/2, 4/3, etc.), Construction and Operation – Servo and Proportional valves: Basic concept – Applications in in hydraulic and pneumatic circuits

Accessories: Reservoirs, Accumulators, Pressure Switches – Applications – Fluid Power ANSI Symbols - Criteria for Selection of Valves

Mechanics of Directional Control: Spool Dynamics, Port and Position Configurations, Center Position Logic

Advanced Regulation Techniques: Load-Sensing (LS), Proportional and Servo Technology, Digital Hydraulics and Pulse Width Modulation (PWM), Industrial Applications

Real World Assignment

1) Analyze a hydraulic or pneumatic system, identify valves, and explain their functions with a circuit diagram

Exemplars / Practical Applications

1) Demonstration of DCV, FCV, and PCV
2) Simulation using FluidSIM or similar software
3) Industrial case study

Unit IV	Pneumatic system components and Industrial applications	(07 Hours)

Compressors - Types, principle of working and constructional details. Comparison of pneumatic with hydraulic power transmissions. Types of filters, pressure regulators, lubricators, mufflers, dryers, direction control valves, pneumatic actuators, shuttle valve, two pressure valve, quick exhaust valve and time delay valves, electropneumatics. Speed regulating methods, pneumatic circuits, reciprocating, cascading time delay etc. Application of pneumatics in low cost automation and in industrial automation.

Real World Assignment

1) Design a speed control circuit using flow control valves for a pneumatic actuator.
2) Study and select appropriate filters, regulators, and lubricators (FRL unit) for a given system.
3) Prepare a maintenance and troubleshooting plan for pneumatic systems in industry.
4) Analyze the role of dryers and mufflers in improving system efficiency and noise reduction

Exemplars / Practical Applications

1) Pneumatic actuators are used in automated assembly lines for fast and repetitive operations.
2) FRL units are used in industries to ensure clean, regulated, and lubricated compressed air supply.
3) Cascading circuits are used in multi-cylinder applications for synchronized operations.
4) Pneumatic systems are used in robotics for lightweight and fast actuation.
5) Mufflers and dryers are used in pneumatic systems to reduce noise and remove moisture from compressed air.

Unit V	Hydraulic and pneumatic circuit design and Automation	(08 Hours)

Calculation of piston velocity, thrust under static and dynamic applications, considering friction, inertia loads, design considerations for cylinders, Design of hydraulic/pneumatic circuits for practical application, selection of different components such as reservoir, control elements, actuators, accumulator, intensifier, filters, pumps. (Students are advised to refer manufacturers' catalogues for design and use simulation tool like Automation Studio for analysis).

Real World Assignment

1) Develop a hydraulic circuit for a press machine using suitable valves, pump, and actuator.
2) Select appropriate components such as reservoir, pump, filters, and actuators using manufacturer catalogues.
3) Design a high-pressure system using an intensifier for industrial applications like metal forming.
4) Simulate a hydraulic/pneumatic circuit using Automation Studio and analyze system performance.
5) Optimize component selection to improve efficiency and reduce energy losses in fluid power systems.

Exemplars

1) Pumps, reservoirs, and filters are used in hydraulic power units for continuous and efficient system operation.

2) Pneumatic systems are used in clamping, material handling, and assembly operations in manufacturing industries.

3) Simulation tools like Automation Studio are used in industries for system design, testing, and optimization.

Learning Resources

Text Books:

1 Anthony , Esposito, " Fluid Power with Applications" ,Pearson Education Inc New Delhi .
2 Majumdar, S.R , "Oil Hydraulic Systems – Principles and Maintenance", McGraw-Hill, New Delhi,

Reference Books:

1. Majumdar, S.R., "Pneumatics Systems – Principles and Maintenance", TataMcGraw Hill, New Delhi
2. Stewart, Harry., "Hydraulics and Pneumatics", Taraporewala Publication
3. Dudley, A. Pease and John T. Pippenger , "Basic Fluid Power", Prentice Hall,
4. Parr, Andrew , "Hydraulics Maintenance & Pneumatics: A Technician's Maintenance Engineers Guide", Butterworth-Heinemann Publisher

MOOC / NPTEL/ YouTube Links: -

1. Prof. Somashekhar S , IIT Madras "NPTEL Web course material"
https://onlinecourses.nptel.ac.in/noc21_me51/preview?utm_source=chatgpt.com

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PEC 361D-MEC: Industrial Engineering

Teaching Scheme		Credit	Examination Scheme	
Theory	3 Hours/Week	3	CCE	30 Marks
Practical	NA		End Sem	70 Marks

Prerequisite Courses, if any:

- Basic concepts of Mathematics and Mechanical Engineering, Industrial Orientation, Quality Control, Human Psychology, Basic Finance, Passion for Continual Improvement

Course Objectives:

1. To INTRODUCE the concepts, principles, and framework of Industrial Engineering and Productivity enhancement approaches.
2. To FAMILIARIZE the students with different time study and work measurement techniques for productivity improvement.
3. To INTRODUCE various aspects of facility design.
4. To ACQUAINT the students with various components and functions of Production Planning and Control.
5. To ACQUAINT the student about inventory management and approaches to control.

Course Outcomes:

Learner will be able to:

CO1. **EVALUATE** the productivity and various productivity improvement techniques.
CO2. **APPLY** work study techniques and with its importance for better productivity.
CO3. **DEMONSTRATE** the ability to **SELECT** plant location, appropriate layout and material handling equipment.
CO4. **IDENTIFY** various Production planning and control tools for effective planning, scheduling and managing the shop floor control.
CO5. **UNDERSTAND** inventory requirements for effective control on manufacturing requirements.

Course Contents

Unit I	Introduction to Industrial Engineering and Productivity	(07 Hours)

Introduction to Industrial Engineering, Historical background and scope, Contribution of Taylor, Gilbreth, Gantt, Maynard, Ford, Deming and Ohno. Importance of Industrial engineering. Introduction to Work system design

Productivity: Definition of productivity, Measures of Productivity, Total Productivity Model, need for Productivity Evaluation, Productivity measurement models, Productivity improvement approaches, Principles, Productivity Improvement techniques – Technology based, Material based, Employee based, Product based techniques. (Numerical on productivity measurement)

Real World Assignment: Understand Productivity Measurement models in a real industrial environment. Select a small-scale industry (Machine shop) 1. Study the Work System and understand Input resources like (labour, material, machine, energy) and Find Output (units produced, value) 2. Calculate Productivity (Labour productivity, Machine productivity, Total productivity)

Exemplars / Practical Applications: Assembly Line Productivity Improvement in an Automobile Industry**.**

Unit II	Work Study	(07 Hours)
Method Study: Introduction and objectives, Areas of application of work study in industry, Selection and Basic procedure. Recording techniques, Operations Process Chart, Flow Process Chart (Man, Machine & Material) Multiple Activity Chart, Two Handed process chart, Flow Diagram, String Diagram and Travel Chart, Cycle and chronocycle graphs, SIMO chart, Therbligs, Micro motion and macro-motion study: Principles of motion economy, Normal work areas and work place design. **Work Measurement**: Techniques, time study, steps, work sampling, Determination of time standards. Observed time, basic time, normal time, rating factors, allowances, standard time, and standard time determination. (Numerical) Introduction to PMTS, MTM, and MOST		
Real World Assignment: Determine standard time using time study and numerical calculations**.**		
Exemplars / Practical Applications: Material movement analysis in a small manufacturing plant / workshop using Flow Diagram & String Diagram.		

Unit III	Production Facility Design	(07 Hours)
Plant Location: Introduction, Factors affecting location decisions, Multi-facility location **Plant Layout**: Principles of Plant layout and Types, factors affecting layout, methods, factors governing flow pattern, travel chart for flow analysis, analytical tools of plant layout, layout of manufacturing shop floor, repair shop, services sectors, and process plant. Layout planning, Quantitative methods of Plant layout and relationship diagrams. Dynamic plant layout **Material Handling**: Objectives and benefits of Material handling, Relationship between layout and Material handling, Equipment selection		
Real World Assignment 1. Design and Analysis of Plant Layout using Travel Chart & Relationship Diagram, 2. Material Handling System Analysis & Equipment Selection		
Exemplars / Practical Applications: Discuss selection of Plant Location for an Automobile Component Manufacturing Unit.		
Unit IV	**Production Planning and Control**	**(07 Hours)**
Types and methods of Production, and their Characteristics, functions and objectives of Production Planning and Control, Steps: Process planning, Loading, Scheduling, Dispatching and Expediting with illustrative examples, Capacity Planning, Aggregate production planning and Master production scheduling. Introduction to a line of balance, assembly line balancing, and progress control **Forecasting Techniques**: Causal and time series models, Moving average, Exponential smoothing, Trend and Seasonality. (Numerical)		
Real World Assignment: Understand and apply PPC functions (process planning, loading, scheduling, dispatching, expediting) in a real system.		
Exemplars / Practical Applications: Aggregate Production Planning in a Seasonal Product Industry, like Manufacturing of air coolers (seasonal demand product).		
Unit V	**Inventory and Inventory Control**	**(07 Hours)**

Materials: Profit Centre: Role of materials management techniques in material productivity improvement, cost reduction and value improvement.

Purchase Management: Purchase management, incoming material control. Acceptance sampling and inspection. Vendor rating system.

Inventory: Functions, Costs, Classifications, Deterministic inventory models and Quantity discount

Inventory Control: EOQ (Numericals), concepts, type of Inventory models-deterministic and probabilistic, Selective inventory control, Fundamental of Material Requirement Planning (MRP-I), Manufacturing Resource Planning (MRP-II), Enterprise Resource Planning (ERP), Just-in-Time system (JIT) and Supply Chain Management (SCM)

Real World Assignment: Economic Order Quantity (EOQ) Analysis for Inventory Control

Exemplars / Practical Applications: Inventory Planning using MRP, ERP & SCM in an Automobile Industry. Managing inventory for car manufacturing (multi-component system).

Learning Resources

Text Books:

1. O. P. Khanna, Industrial engineering and management, Dhanpat Rai publication
2. M Mahajan, Industrial Engineering and Production Management, Dhanpat Rai and Co.
3. Martend Telsang, Industrial Engineering, S. Chand Publication.
4. Banga and Sharma, Industrial Organization& Engineering Economics, Khanna publication.

Reference Books:

1. Askin, Design and Analysis of Lean Production System, Wiley, India
2. Introduction to Work Study by ILO, ISBN 978-81-204-1718-2, Oxford & IBH Publishing Company, New Delhi, Second Indian Adaptation, 2008.
3. H. B. Maynard, K Jell, Maynard's Industrial Engineering Hand Book, McGraw Hill Education.
4. Zandin K.B., Most Work Measurement Systems, ISBN 0824709535, CRCPress,2002
5. Martin Murry, SAP ERP: Functionality and Technical Configuration, SAP Press.
6. Barnes, Motion and time Study design and Measurement of Work, Wiley India
7. Sumanth, D.J, "Productivity Engineering and Management", TMH, New Delhi, 1990.
8. Edosomwan, J.A, "Organizational Transformation and Process re- Engineering", British Cataloging in publications, 1996.
9. Prem Vrat, Sardana, G.D. and Sahay, B.S, "Productivity Management - A systems approach", Narosa Publications, New Delhi, 1998.
10. Francis, R.L., and White, J.A, "Facilities layout and Location", Prentice Hall of India, 2002.
11. James A. Tompkins, John A. White, "Facilities Planning", Wiley, 2013
12. Richard L. Francis, Leon F Mc Ginnes and John A. White, "Facility Layout and Location- An Analytical Approach", PHI, 1993
13. G. K. Agarawal, "Plant Layout and Material Handling", Jain Brothers, 2007

MOOC / NPTEL/ YouTube Links: -

1. https://archive.nptel.ac.in/courses/112/107/112107143/#
2. https://nptel.ac.in/courses/112107249
3. https://onlinecourses.nptel.ac.in/noc22_me04/preview
4. https://nptel.ac.in/courses/112107292
5. https://nptel.ac.in/courses/112107142

Savitribai Phule Pune University Third Year of Mechanical Engineering (2024 Pattern)				
PEC 362A-MEC: Product Design and Development				
Teaching Scheme		**Credit**	**Examination Scheme**	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End Sem**	**70 Marks**

Prerequisite Courses, if any:

- Basic Engineering Science-Physics, Chemistry, Material Science, Engineering Metallurgy, Manufacturing processes, etc

Course Objectives:

1) To LEARN and UNDERSTAND fundamentals of product design and development process.
2) To UNDERSTAND and LEARN market survey, customer need analysis and product specifications finalization.
3) To UNDERSTAND and LEARN concept generation, evaluation and product architecture.
4) To LEARN and UNDERSTAND Reverse Engineering, Benchmarking and Product optimization.
5) To LEARN and UNDERSTAND Design for X, Prototyping and product life cycle management.

Course Outcomes:

After successful completion of the course, learner will be able to: On completion of the course, learner will be able to

CO1: EXPLAIN and **APPLY** the fundamentals of product design and development process, including design phases, planning, and product lifecycle considerations.

CO2: **ANALYZE** market requirements by conducting customer need analysis, market survey, and formulate product specifications based on Voice of Customer (VoC).

CO3: GENERATE, **EVALUATE**, AND SELECT product concepts and develop product architecture using systematic design methodologies.

CO4: **APPLY** reverse engineering, competitive benchmarking, and optimization techniques to improve existing product designs.

CO5**: IMPLEMENT** Design for X (DfX) principles, prototyping methods, and product lifecycle management (PLM) strategies in product development.

Course Contents

Unit I	**Fundamentals of Product Design & Development**	**(07 Hours)**

- Definition & need of Product Design & Development
- Importance of engineering & industrial design
- Essential factors for product design
- Product design phases and generic product development process
- Product Development Vs Product Design
- Standardization, simplification & specialization in product design
- Steps in Product Development
- Product development team & product development planning
- Modern product development process
- Product testing
- Product validation & product verification

Real World Assignment

1. Product Design Process Case Study:

- Select a real product (e.g., electric kettle, bicycle, smartphone).
- Study product design phases, development process, and role of engineering and industrial design.
- Compare Product Design vs Product Development.
- Submit a structured report with diagrams.

2. Product Redesign & Standardization Study:
- Select an existing product with usability issues.
- Identify design flaws and lack of standardization.
- Propose improved design with testing and validation aspects.
- Present with sketches/models.

Exemplar / Practical Applications/CCE

1. Product Development Planning Exercise:
- Form teams of 3–4 students.
- Select a simple product (e.g., water bottle, chair).
- Prepare product development steps, team roles, and planning.
- Develop timeline using Gantt chart.
- Evaluate based on feasibility and planning.

2. Product Testing & Validation Demonstration:
- Select a small product.
- Conduct functionality, safety, and usability testing.
- Perform verification vs validation comparison.
- Document observations and suggest improvements.

Unit II	Product Development: Customer Need Analysis & Market Considerations	(07 Hours)

Mission statement & technical questioning, Voice of customer (VoC) & customer need identification, Types & models of customer needs, Methods of gathering customer needs, Analysis of gathered data, Technology forecasting & S-curve, Customer population & market segmentation, Establishing engineering characteristics, Quality Function Deployment (QFD) & House of Quality (HOQ),Competitive benchmarking, Economic analysis of product.

Real World Assignment

1. Voice of Customer (VoC) Study:
- Select a product (e.g., backpack, mobile app, home appliance).
- Conduct survey/interviews (minimum 10 users).
- Identify customer needs and pain points.
- Classify needs (basic, performance, excitement).
- Prepare report with charts.

2. QFD & Competitive Benchmarking:
- Select a product category (e.g., electric scooter).
- Perform competitive benchmarking (2–3 products).
- Develop House of Quality (HOQ).
- Map customer needs to engineering characteristics.
- Suggest best design strategy.

Exemplar / Practical Applications/CCE

1. Market Segmentation Exercise:
- Choose a product.
- Identify target customers and segmentation (age, income, usage).
- Analyze customer population.
- Present market positioning.

2. Technology Forecasting & S-Curve Analysis:
- Select a technology (e.g., EVs, smartphones).

- Plot technology growth using S-curve.
- Predict future trends and opportunities.
- Submit graphical analysis.

Unit III	Product Development: Concept Generation, Evaluation & Product Architecture	(08 Hours)

Product information gathering ,Creative thinking & problem solving techniques ,Brainstorming, lateral thinking, Gordon technique, checklist method ,Morphological analysis & attribute listing ,Concept generation technique, Concept selection method (Pugh's method, scoring method), Concept selection design evaluation, estimation & technical feasibility ,Process of concept embodiment ,Product architecture & its types, System modeling, functional modeling & decomposition, FAST method , Subtract & operate procedure

Real World Assignment

1. Pugh's concept selection

Students will pick a product, generate multiple design concepts, and evaluate them against a reference/datum using criteria like cost, ease of use, safety, etc.

Product example:- Foldable Study Table**,** Helmet for Two-Wheeler Riders, Reusable Water Bottle etc.

2.FAST (Function Analysis System Technique) Method

Students will build a FAST diagram showing **Why** → **How** function relationships for a product, identifying basic, secondary, and unwanted functions.

Product example:- Bicycle, Ceiling Fan , Laptop Bag etc.

Exemplar / Practical Applications/CCE

Pugh's Concept Selection Matrix Students select a everyday product they personally use such as a water bottle, backpack, or phone stand conduct brief user interviews with 3–5 peers to identify key needs, generate at least 4 design concepts.

FAST Method Students disassemble or closely examine a simple household product such as a stapler, hand pump, or electric torch.

Unit IV	Reverse Engineering, Benchmarking and Product Optimization	(07 Hours)

Product teardown process and methods, Applications of reverse engineering, Force flow diagrams, Measurement and experimentation techniques, Benchmarking approach and detailed procedure, Tools used in benchmarking, Indented assembly and cost analysis, Function–form diagrams, Trend analysis and product improvement. Product specification setting, Introduction to product portfolio and product architecture.

Real World Assignment

1.Product teardown & Benchmarking

Students will disassemble or closely examine a simple household product in 3- 4 peers such as Bicycle (complete or subsystem like gear/brake) ,Two-wheeler helmet ,Car wiper mechanism ,Fuel pump (demo model) electric iron, mixer grinder, smartphone charger, or water pump, to understand its construction and working. They will identify components, understand how each part contributes to overall functionality, prepare function–component mapping and block diagrams, and estimate the manufacturing cost by calculating the cost of individual components and comparing it with the market price.

2.Benchmarking

Students will perform benchmarking by selecting at least three similar products and comparing them based on cost, performance, features, material, and efficiency. They will also evaluate product performance by defining parameters such as efficiency, power, and durability, conduct simple experiments, and finally suggest improvements based on the benchmarking analysis.

Exemplar / Practical Applications/CCE

Students will perform reverse engineering of a small component or product, including teardown and benchmarking, and propose an improved design. In this students will able to understand the following process-

- Perform **product teardown** to identify components and working
- Prepare **function–component mapping and basic diagrams**
- Conduct **benchmarking** with similar products
- Analyze performance, cost, and materials
- Identify limitations of the existing design

- Propose a **redesign with improved specifications**

Unit V	Design for X (DFX), Prototyping and Product Lifecycle Management	(07 Hours)

- Design for Manufacturing (DFM) and Design for Assembly (DFA/DFMA)
- Design for reliability, safety and robustness
- Design for environment and sustainability
- Design for serviceability and user-friendly design
- Manufacturing cost analysis
- Life Cycle Assessment (LCA) – basic and weighted method
- Role of computers in product design and manufacturing
- Rapid prototyping techniques: SLA, SLS, FDM, LOM, BPM
- Introduction to 3D printing technologies
- Product Life Cycle Management (PLM): concepts and elements
- Product data management and workflow
- Case studies on product design and development

Real World Assignment

1. Case Study On Product design and development of simple products like e.g., mixer grinder,bicycle, brake system of Two wheeler
2. Reliability & Safety Evaluation of a Mechanical System
3. Sustainable Product Redesign using eco-friendly materials
4. Manufacturing Cost Estimation and cost reduction strategies

Exemplar / Practical Applications

1. Introduction to use simulation tools (FEA/CFD) to test product performance before manufacturing.
2. Introduction to Integration of design, manufacturing, and supply chain data using PLM software. E.g: Windchill

Learning Resources

Text Books:

1. Product Design and Development
   Karl T. Ulrich, Steven D. Eppinger, Maria C. Yang, McGraw-Hill Education.
2. Product Design and Development
   Prof. Mandar M. Bidwe, TechKnowledge Publications.
3. Introduction to Product Design and Development for Engineers
   Ali Jamnia, CRC Press.

Reference Books:

1. Product Design for Manufacture and Assembly
   Geoffrey Boothroyd, Peter Dewhurst.
2. Product Design and Manufacturing
   A. C. Chitale, R. C. Gupta.
3. New Product Development
   Tim Jones, Butterworth-Heinemann.
4. Product Design Fundamentals and Methods

MOOC / NPTEL/ YouTube Links: -

1. NPTEL: Product Design and Development
   Available on NPTEL platform – Covers product lifecycle, design process, QFD, prototyping, and development strategies.
2. NPTEL: Design Thinking
   Focuses on customer-centric product design, innovation, and problem-solving approaches.
3. MIT OpenCourseWare (YouTube): Product Design & Engineering Design Lectures
   Provides real-world case studies and structured engineering design methodologies.
4. Learn Engineering (YouTube Channel)
   Offers visual and conceptual explanations of product design, manufacturing, and engineering fundamentals.

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PEC362B-MEC : Smart Thermal Engineering Systems

Teaching Scheme	Credit	Examination Scheme
Theory : 2 Hours/Week	3	CCE : 30 Marks End-Semester :70 Marks

Prerequisite Courses, if any:
Fluid Mechanics; Engineering Thermodynamics; Engineering Mathematics

Course Objectives:

1. To INTRODUCE the concept of smart thermal systems integrating sensors, control systems, and digital technologies.
2. To UNDERSTAND monitoring and control of thermal systems using IoT and smart instrumentation.
3. To ANALYZE energy efficiency and predictive maintenance in thermal engineering systems.
4. To EXPLORE applications of smart technologies in HVAC, power plants, and renewable energy systems.
5. To DEVELOP problem-solving skills for designing intelligent and sustainable thermal engineering systems.

Course Outcomes:

After successful completion of the course, students will be able to:

CO1: EXPLAIN the concept and components of smart thermal engineering systems.

CO2: ANALYZE sensor and instrumentation technologies used for monitoring thermal systems.

CO3: APPLY IoT technologies for remote monitoring and data acquisition in thermal systems.

CO4: EVALUATE smart control strategies for optimizing thermal system performance.

CO5: DESIGN smart and energy-efficient thermal engineering solutions for modern industrial applications.

Course Contents

Unit I	Introduction to Smart Thermal Systems	(06 Hours)

Concept of smart engineering systems and Industry 4.0. Overview of traditional vs smart thermal systems. Components of smart thermal systems including sensors, controllers, communication networks, and actuators. Smart monitoring and automation in thermal systems. Basics of cyber-physical systems and digital twins in thermal engineering applications.

Building Automation Systems (BAS): Concept and architecture of building automation; integration of HVAC, lighting, and energy management systems; role of sensors, controllers, and communication protocols in smart buildings; energy efficiency and occupant comfort optimization.

Applications of smart technologies in thermal engineering such as smart boilers, smart HVAC systems, smart refrigeration systems, and intelligent power plants.

Introduction to thermal system modeling and digital data acquisition.

Real World Assignment

1. Analyze energy consumption data of a building and suggest smart improvements.
2. Study a real building and identify scope for **Building Automation System (BAS)** implementation.

3. Develop a basic **IoT-based temperature monitoring system** using Arduino.
4. Poster presentation on "Role of Industry 4.0 in Thermal Engineering".

Exemplar / Practical Applications

1. Smart HVAC systems in green buildings
2. Smart monitoring of industrial boilers
3. Digital twins in power plants
4. Intelligent refrigeration systems in supermarkets

Unit II	Sensors and Instrumentation for Thermal Systems	(06 Hours)

Overview of measurement systems used in thermal engineering. Sensors for temperature, pressure, flow rate, humidity, and heat flux.

Temperature measurement: Thermocouples, RTDs, thermistors, and infrared sensors.

Pressure measurement: Manometers, pressure transducers, and piezoelectric sensors.

Flow measurement techniques: Orifice meters, venturi meters, rotameters, ultrasonic flow meters, and hot wire anemometer for air flow measurement.

Humidity and air quality measurement: Humidity sensors, indoor air quality (IAQ) sensors for HVAC applications, measurement of parameters such as CO_2, VOCs, and particulate matter.

Advanced applications: Integration of sensors with Artificial Intelligence (AI) for smart monitoring, predictive maintenance, and control in thermal systems; applications in medical and healthcare sectors (ventilators, patient monitoring, and controlled environments).

Data acquisition systems, signal conditioning, and calibration of sensors and uncertainty analysis.

Real World Assignment

1. Students develop a temperature and humidity monitoring system using microcontrollers (Arduino / Raspberry Pi) to monitor room thermal conditions.
2. Mini project to Design a data acquisition system for temperature and humidity monitoring

Exemplar / Practical Applications

1. Temperature monitoring in industrial furnaces
2. Flow monitoring in pipelines
3. Environmental monitoring in HVAC systems
4. Thermal monitoring of electronic devices

Unit III	IoT and Smart Monitoring of Thermal Systems	(06 Hours)

Introduction to Internet of Things (IoT) architecture. Communication technologies used in smart systems such as Wi-Fi, Bluetooth, LoRa, and cloud platforms.

Smart data acquisition and remote monitoring of thermal systems. Cloud-based monitoring platforms.

Applications of IoT in thermal engineering including smart HVAC systems, smart energy monitoring, and smart refrigeration., Smart monitoring in agriculture (e.g., greenhouse climate control, soil moisture and temperature monitoring, irrigation automation, and cold storage for agricultural produce).

Concept of predictive maintenance and fault detection in thermal equipment.

Introduction to digital twins for monitoring and optimizing thermal systems.

Real World Assignment

1. Students build a simple IoT-based temperature monitoring system where sensor data is transmitted to a cloud platform and displayed on a mobile dashboard.
2. Analyze IoT data from a thermal system and identify performance trends
3. Build a smart greenhouse monitoring system (temperature + humidity + irrigation control)
4. Case Studies IoT-based predictive maintenance in HVAC or power plants

Exemplar / Practical Applications

1. Remote monitoring of boilers and heat exchangers
2. IoT-enabled HVAC systems in smart buildings
3. Industrial energy monitoring systems
4. Cold chain monitoring for food and pharmaceuticals

Unit IV	Smart Control of Thermal Systems	(06 Hours)

Introduction to control systems in thermal engineering. Open loop and closed loop control systems.

Control strategies used in thermal systems including on-off control, PID control, and adaptive control.

Smart control algorithms for energy optimization; application of PLCs in automation and control of thermal systems.

Integration of artificial intelligence and machine learning in thermal system control.

Applications in smart HVAC systems, refrigeration plants, and power plant operation.

Energy management and optimization of thermal systems.

Real World Assignment

1. Students analyze energy consumption of air conditioning systems in a building and propose smart control strategies for energy savings.
2. Implement PID control for temperature regulation (simulation or hardware)
3. Develop a PLC-based control logic for boiler or HVAC system (ladder diagram)

Exemplar / Practical Applications

1. Smart thermostat systems in buildings
2. Automated control of industrial boilers
3. Energy optimization in refrigeration plants
4. Intelligent building energy management systems

Unit V	Smart Energy Systems and Future Thermal Technologies	(06 Hours)

Integration of renewable energy systems with thermal systems including solar thermal systems, geothermal systems, and waste heat recovery systems.

Smart district heating and cooling systems.

Energy efficiency and sustainability in thermal systems.

Smart boiler systems with automated control and efficiency optimization; smart cold storage systems for food and pharmaceutical applications with real-time monitoring and temperature control; thermal management in pharmaceutical industries including cleanroom HVAC, cold chain logistics, and precision temperature control.

Future technologies including AI-driven thermal system optimization, digital twins, and autonomous thermal management systems.

Real World Assignment

1. Students perform a basic energy audit of a building HVAC system and suggest smart technologies to improve efficiency.

2. DIY model of **Solar Water Heater /Smart Cold Storage Box**

Exemplar / Practical Applications

1. Smart district heating networks
2. Solar-assisted HVAC systems
3. Waste heat recovery in industries
4. Smart energy systems in sustainable buildings

Learning Resources

Text Books:

1. Thermal System Design and Optimization – C. Balaji Springer.
2. Thermal Energy Systems: Design, Computational Techniques and Applications – Ashwani Kumar et al. CRC Press.
3. Smart Heat Transfer and Thermal Management: Leveraging AI, Machine Learning, and Soft Computing – Raj Kumar Arya et al. Woodhead / Elsevier.

Reference Books:

1. Artificial Intelligence and Machine Learning in Heat Transfer Optimization for Sustainable Energy Systems – J. Heeraman & P. Barmavatu
   CRC Press.
2. Intelligent Thermal Energy Systems: An Overview , Nova Science Publishers.

MOOC / NPTEL/YouTube Links: -

1. https://onlinecourses.nptel.ac.in/noc26_ee29/preview
2. https://onlinecourses.nptel.ac.in/noc21_ee32/preview
3. https://www.udemy.com/course/iot-practice-with-temperature-sensor-data/?srsltid=AfmBOorPoBeSmqGDJ57S9gCTUGydP7x6J4pK2qtt_mC7_Hg44G8EeQT7
4. https://www.udemy.com/course/a-complete-course-on-an-iot-system-design-and-development/?srsltid=AfmBOopesS9z_XPnfhwEnxVtVEGzYmPSMduRuEor-IasiWmTmz3czIlS

Savitribai Phule Pune University
Third Year of Mechanical Engineering (2024 Pattern)

PEC 362C-MEC : Compressible Flow

Teaching Scheme	Credit	Examination Scheme
Theory : 3 Hours/Week	**3**	**CCE : 30 Marks** **End-Semester :70 Marks**

Prerequisite Courses, if any:
Fluid Mechanics; Engineering Thermodynamics; Engineering Mathematics

Course Objectives:
1. To INTRODUCE the fundamental concepts of compressible fluid flow and the role of Mach number in high-speed flows.
2. To UNDERSTAND thermodynamic and fluid dynamic relations governing compressible flows.
3. To ANALYZE flow behavior in ducts, nozzles, diffusers, and pipelines under compressible conditions.
4. To STUDY shock waves, expansion waves, and their effects in engineering systems.
5. To APPLY compressible flow principles to real-world aerospace, propulsion, and turbomachinery applications.

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

CO1: APPLY fundamental principles of compressible flow to analyze flow properties, Mach number, and isentropic relations in engineering systems.

CO2: ANALYZE isentropic flow behavior and evaluate nozzle performance using area–Mach number relations and choking conditions.

CO3: ANALYZE normal and oblique shock waves and expansion phenomena to determine flow property variations in supersonic flows.

CO4: EVALUATE the effects of friction and heat transfer on compressible flow in ducts using Fanno and Rayleigh flow models.

CO5: APPLY compressible flow concepts to analyze real-world engineering systems in aerospace, turbomachinery, energy, and thermal applications.

Course Contents

Unit I	Fundamentals of Compressible Flow	(06 Hours)

Introduction to compressible flow; definition and characteristics of compressible fluids; comparison between compressible and incompressible flow; thermodynamic properties of gases; speed of sound; Mach number and its significance; classification of flows based on Mach number (subsonic, sonic, transonic, supersonic, hypersonic); stagnation properties; total temperature and pressure; isentropic relations for compressible flow; energy equation for compressible systems.

Real World Assignment
1. Students measure air velocity using a small air blower and pitot tube and estimate Mach number under different operating conditions. Analyze whether compressibility effects become significant.
2. Develop a simple MATLAB / Python script that calculates Mach number, stagnation pressure, and

temperature for various inlet conditions of air flow in ducts.

3. Visit to Air Handling / Compressor Systems in Industry.
4. Case Study on "Why Compressibility is Critical in Aircraft but Negligible in Cars".

Exemplar / Practical Applications

1. Air flow in high-speed aircraft wings
2. Flow in gas turbines and jet engines
3. High-speed wind tunnel testing
4. Flow in rocket propulsion systems

Unit II	Isentropic Flow and Area–Velocity Relations	(06 Hours)

Isentropic flow assumptions; governing equations for one-dimensional compressible flow; derivation of isentropic relations; area–velocity relation; area–Mach number relation; flow through converging and converging-diverging nozzles; choking phenomenon; critical properties; nozzle efficiency; performance analysis of nozzles.

Real World Assignment

1. Calculate nozzle exit velocity and Mach number for a jet engine nozzle using given stagnation conditions.
2. Design a converging-diverging nozzle using simulation tools (ANSYS / MATLAB) and study variation of Mach number and pressure distribution along the nozzle.
3. Case Study on "Nozzle Design in ISRO rocket engines".

Exemplar / Practical Applications

1. Rocket engine nozzles
2. Supersonic wind tunnels
3. Gas turbine exhaust nozzles
4. Industrial gas expansion systems

Unit III	Normal Shock Waves, Oblique Shock Waves and Expansion Waves	(06 Hours)

Shock waves and their physical significance; formation of normal shock waves; governing equations across normal shocks (continuity, momentum, energy); Rankine–Hugoniot relations; property changes across shock waves; stagnation pressure loss across shocks; shock wave tables and charts; shock wave analysis in ducts and nozzles.

Oblique shock waves; flow deflection by wedges; shock angle–Mach number relations; θ–β–M relation; weak and strong shock solutions; Prandtl–Meyer expansion waves; expansion fans; supersonic flow over convex and concave surfaces; compressible flow over airfoils.

Real World Assignment

1. Using standard normal shock tables, determine downstream pressure, temperature, and Mach number for given upstream conditions.
2. Create a computational tool or spreadsheet to predict shock properties for varying upstream Mach numbers.
3. Analyze supersonic flow over a wedge-shaped object and calculate shock angle and downstream Mach number.
4. Using CFD or analytical tools, simulate supersonic flow over a wedge and visualize shock formation

Exemplar / Practical Applications

1. Supersonic aircraft wing design
2. Shock formation in rocket propulsion systems
3. Shock waves in supersonic wind tunnels
4. Missile aerodynamics

Unit IV	Compressible Flow with Friction and Heat Transfer	(06 Hours)

Flow in constant area ducts with friction (Fanno flow); governing equations and Fanno line; effects of friction on Mach number; flow with heat transfer (Rayleigh flow); Rayleigh line analysis; choking in ducts; combined effects of friction and heat transfer; compressible flow in pipelines; industrial applications.

1. Analyze pressure loss in a long gas pipeline using compressible flow equations.
2. Develop a computational model to simulate Fanno and Rayleigh flow conditions in industrial pipelines.
3. Industrial Visit to Study Gas/Steam Pipeline Systems (Thermal power plants / process industries)
4. Poster Presentation on “Fanno Flow vs Rayleigh Flow – Engineering Significance”

Unit V	Applications of Compressible Flow	(06 Hours)

Aerospace Applications: Flow through convergent-divergent nozzles in rockets and jet engines

Turbo-machinery Applications: Compressible flow in axial and centrifugal compressors, gas turbines, and steam turbines

Power and Energy Systems: Applications in thermal power plants (steam nozzles, turbines); gas dynamics in combustion chambers; exhaust systems of IC engines

HVAC and Refrigeration Systems: Refrigerant flow through expansion devices (valves, capillary tubes); choking in ducts

Biomedical Engineering: Gas flow in respiratory systems, ventilators, and anesthesia delivery systems.

Electronics Cooling: High-speed air cooling of servers and data centers.

Renewable Energy: Wind tunnel testing for wind turbine

Real World Assignment

1. Case Study / Field Study: HVAC & Refrigeration Systems

2. Seminar / Group Presentation on “Future of Supersonic Transport” or “Role of Compressible Flow in Sustainable Energy Systems”

Exemplar / Practical Applications

1. Gas transmission pipelines
2. Combustion chambers of jet engines
3. Heat addition in propulsion systems
4. High-speed air delivery systems in industry

Learning Resources

Text Books:

1. Modern Compressible Flow with Historical Perspective — John D. Anderson Jr. McGraw-Hill Education.
2. Fundamentals of Gas Dynamics — Robert D. Zucker and Oscar Biblarz Wiley Publication.
3. Gas Dynamics — E. Rathakrishnan, PHI Learning.

Reference Books:

1. The Dynamics and Thermodynamics of Compressible Fluid Flow — Ascher H. Shapiro (Vol. 1 & 2)
2. Elements of Gas Dynamics — H. W. Liepmann and A. Roshko
3. Gas Dynamics — Maurice J. Zucrow and Joe D. Hoffman
4. Fundamentals of Compressible Flow — S. M. Yahya
5. Compressible Fluid Flow — Patrick H. Oosthuizen and William E. Carscallen

MOOC / NPTEL/YouTube Links: -

1. https://onlinecourses.nptel.ac.in/noc21_me123/preview

Savitribai Phule Pune University

Third Year of Mechanical Engineering (2024 Pattern)

PEC 362D-MEC: Advanced Machining Processes

Teaching Scheme		Credit	Examination Scheme	
Theory	**3 Hours/Week**	**3**	**CCE**	**30 Marks**
Practical	**NA**		**End Sem**	**70 Marks**

Prerequisite Courses, if any:

- Basic Engineering Science - Physics, Chemistry, Material Science, Engineering Metallurgy, Manufacturing processes

Course Objectives:

1. To ANALYZE AND IDENTIFY applications of special forming processes.
2. To ANALYZE AND IDENTIFY applications of advanced joining processes.
3. To UNDERSTAND AND ANALYZE the basic mechanisms of hybrid non-conventional machining techniques
4. To UNDERSTAND various applications and methods of micro and nano fabrication techniques.
5. To UNDERSTAND AND ANALYZE sustainable machining techniques.

Course Outcomes:

Learner will be able to:

CO1. **CLASSIFY** various special forming processes.

CO2. **IDENTIFY** applicability of advanced joining processes.

CO3. **UNDERSTAND** the basic mechanisms of hybrid non-conventional machining techniques.

CO4. **SELECT** appropriate micro and nano fabrication techniques for engineering applications.

CO5. **UNDERSTAND** various sustainable machining techniques for product development.

Course Contents

Unit I	Special Forming Processes	(07 Hours)

Principle, Machines, Process variables, characteristics, advantages, limitations and application of:

High Energy Rate Forming process (HERF), High Velocity Forming (HVF), Explosive forming, Magnetic pulse forming, Electro hydraulic forming, Metal spinning, Flow forming, Stretch forming, Incremental sheet metal forming, Petro-forge forming, Micro forming, Micro coining, Micro extrusion, Micro bending/laser bending, fine blanking.

Real World Assignment: (Case Studies) Industrial applications of special forming processes, Recent trends and advancements.

Exemplars / Practical Applications: Automotive Panel Manufacturing using High Velocity & Stretch Forming

Unit II	Advanced Joining Processes	(07 Hours)

Friction stir welding, Electron Beam welding, Laser beam welding, Ultrasonic welding, Under water welding, Cryogenic welding, Thermal spray coatings, Welding of plastics and composites, Explosive joining, Adhesive bonding

Real World Assignment: (Industrial Applications and Case Studies) Automotive, aerospace, and electronics applications, Recent trends and research developments.

Exemplars / Practical Applications:

1. Aerospace Panel Fabrication using Friction Stir Welding (FSW) & Laser Beam Welding (LBW),
2. Automotive & Electronics Manufacturing using Ultrasonic Welding & Adhesive Bonding.

Unit III	Hybrid Non-conventional Machining Techniques	(07 Hours)

Introduction, classification, and principles of hybrid machining processes; Abrasive flow finishing (AFF), Magnetic abrasive finishing (MAF), Abrasive water-jet machining (AWJM), Wire electric discharge machining (WEDM), Electrochemical grinding (ECG), Electrochemical Deburring (ECD), Shaped tube electrolytic machining (STEM), Electro-jet Machining (EJM), Electrolytic In-process dressing (ELPD), Ultrasonic assisted EDM, Rotary EDM, Electrochemical discharge Machining (ECDM), Laser surface treatments.

Real World Assignment: Industry Case Study on Laser surface treatment in gear hardening

Exemplars / Practical Applications: Precision Finishing of Complex Internal Passages using AFF & MAF, Finishing of fuel injector and nozzles (internal channels).

Unit IV	Micro Machining and Nano Fabrication Techniques	(07 Hours)

Introduction, need of micro and nano machining, Machine/setup, Process parameters, Mechanism of material removal, Applications, Advances of the Diamond Turn machining, Ultrasonic micromachining, Focused Ion Beam Machining, Lithography, photochemical machining, Challenges in micro and nano fabrication techniques.

Real World Assignment: (Application of Micro/Nano Machining in Modern Industry) Diamond turning in optical component fabrication.

Exemplars / Practical Applications:

1. Micro-hole Drilling in Glass using Ultrasonic Micromachining & FIB

Unit V	Sustainable Machining	(07 Hours)

Introduction to sustainable Manufacturing, Environmental impact on sustainable machining. **Advance sustainable machining techniques-** Dry Machining, Minimum Quantity lubrication (MQL), Cryogenic machining, High speed machining. **Waste Reduction in Machining-** Types of waste: chips, fluids, emissions, Chip management and recycling, Zero-waste machining strategies. Role of cutting Fluids in promoting sustainable machining, Energy Efficiency in machining.

Real World Assignment: Study existing machining processes (turning, milling, drilling), dentify sustainability gaps: Energy usage, Coolant usage, Waste generation

Exemplars / Practical Applications: Dry Machining- Cast iron machining in automotive industry: Eliminates coolant completely due to self-lubricating graphite structure.

Learning Resources

Text Books:

1. V. K. Jain, "Advanced Machining Processes", Allied Publishers Pvt. Ltd.
2. M. P Groover., Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, 6th Edition, Wiley 2015
3. A. Ghosh, A. K. Mallik, Manufacturing Science, Affiliated East-West Press Pvt. Ltd., New Delhi
4. U.S. Dixit, D.K. Sarma, J. Paulo Davim, Environmentally Friendly Machining

Reference Books:

1. ASM: Metal Handbook, Volume 6, "Welding, Brazing and Soldering", Metal Park, Ohio.
2. ASM: Metal Handbook, Volume 14, "Forming", Metal Park, Ohio.
3. R. Balasubramaniam, RamaGopal V. Sarepaka, SathyanSubbiah, Diamond Turn Machining: Theory and Practice, CRC Press, ISBN 9781138748323 - CAT# K32643
4. V. K. Jain, Micro manufacturing Processes, CRC Press ISBN-13: 978-1138076426 ISBN-10: 1138076422

MOOC / NPTEL/ YouTube Links: -

1. High Energy Rate Forming process - https://www.youtube.com/watch?v=XNG3ewS39Lw
2. Micro Machining Processes - https://www.youtube.com/watch?v=lAHkOVEHNKA
3. Advance Welding & Joining Techniques - https://onlinecourses.nptel.ac.in/noc22_me124/preview
4. Non Traditional Manufacturing - https://www.youtube.com/watch?v=cxU1zUOpGLk
5. Non-Conventional Machining - https://www.youtube.com/watch?v=g8rqd1PGXnA
6. Fundamentals of micro and nanofabrication - https://onlinecourses.nptel.ac.in/noc19_bt29/preview
7. Sustainability through Green Mfg. Systems https://onlinecourses.nptel.ac.in/noc21_mg85/preview
8. Advanced Machining Processes - https://www.youtube.com/watch?v=CoCWID1T3Jo

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