सावित्रीबाई फुले पुणे विद्यापीठ

Savitribai Phule Pune University, Pune Maharashtra, India

Faculty of Science and Technology

ME-Mechanical Engineering (2025 Pattern)

M.E. Mechanical (Computer Aided Design, Manufacture & Engineering)

(With effect from Academic Year 2025-26)

www.unipune.ac.in

First Year ME–Mechanical Engineering (2025 Pattern)

M.E. Mechanical

(Computer Aided Design, Manufacture & Engineering)

NEP 2020 Compliant Curriculum Structure

Course Code	Course Type	Course Name	Teaching Scheme Hrs./week		Examination Scheme and Marks						Credits		
			L	P	CCE	ESE	TW	PR	OR	Total	L	P	Total
Semester I													
PCC-501-CME	Programme Core Course	Advance Machine Design	4	-	50	50	-	-	-	100	4	-	4
PCC-502-CME	Programme Core Course	Computer Aided Design	4	-	50	50	-	-		100	4	-	4
PCC-503-CME	Programme Core Course	Automated Manufacturing System Modeling	4	-	50	50	-	-	-	100	4	-	4
PCC-504-CME	Programme Core Course	Finite Element Method	4	-	50	50	-	-	-	100	4	-	4
PCC-505-CME	Laboratory-I	Laboratory Practice-I	-	4	-	-	25	-	25	50	-	2	2
PEC-521-CME	Programme Elective Course	Elective - I	3	-	50	50	-	-	-	100	3	-	3
PEC-522-CME	Programme Elective Course	Elective 1-Fieldwork Assignments	-	2	-	-	25	-	25	50	-	1	1
Total			**19**	**6**	**250**	**250**	**50**	**00**	**50**	**600**	**19**	**3**	**22**

List of Elective I Courses:

PEC-521-CME-A	Product Design and Development
PEC-521-CME-B	Rapid Prototyping and Tooling
PEC-521-CME-C	Computer Aided Tool Design
PEC-521-CME-D	Optimization Techniques

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Course Code	Course Type	Course Name	Teaching Scheme Hrs./week		Examination Scheme and Marks						Credits		
			L	P	CCE	ESE	TW	PR	OR	Total	L	P	Total
Semester II													
PCC-551-CME	Programme Core Course	Computer Integrated Manufacturing	4	-	50	50	-	-		100	4	-	4
PCC-552-CME	Programme Core Course	Industrial Product Design & Product Life Cycle Management	4	-	50	50	-	-		100	4	-	4
PCC-553-CME	Programme Core Course	Simulation and Modelling	4	-	50	50	-	-		100	4	-	4
PCC-554-CME	Programme Core Course	Laboratory Practice-II	-	4	-	-	25	-	25	50	-	2	2
PEC-571-CME	Programme Elective Course	Elective - II	3	-	50	50	-	-		100	3	-	3
PEC-572-CME	Programme Elective Course	Elective - III	3	-	50	50	-	-		100	3	-	3
SEM-581-CME	Seminar	Seminar I	-	4	-	-	25	-	25	50	-	2	2
Total			**18**	**8**	**250**	**250**	**50**	**00**	**50**	**600**	**18**	**4**	**22**

List of Elective I Courses:

PEC-571-CME-A	Energy Audit and Management
PEC-571-CME-B	Project and Financial Management
PEC-571-CME-C	Technology Transfer
PEC-571-CME-D	Intellectual Property Rights

List of Elective I Courses:

PEC-572-CME-A	Advanced Materials and Alloys
PEC-572-CME-B	Composites and Ceramics
PEC-572-CME-C	Robotics and Automation
PEC-572-CME-D	Computational Fluid Dynamics

First Year ME–Mechanical Engineering (2025 Pattern)

M.E. Mechanical
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Cours e Code	Course Type	Course Name	Teaching Scheme Hrs./week		Examination Scheme and Marks						Credits		
			L	P	CCE	ESE	TW	PR	OR	Total	L	P	Total
Semester III													
RM-601-CME	Research Methodology	Research Methodology	5	-	50	50	-	-	-	100	5	-	5
OJT-602-CME	On Job Training/ Internship	On Job Training/ Internship	-	10	-	-	100	-	-	100	-	5	5
SEM-603-CME	Seminar II	Seminar II	-	6	-	-	25	-	25	50	-	3	3
RPR-604-CME	Research Project	Project Stage-I	-	18	-	-	25	-	25	50	-	9	9
Total			**5**	**34**	**50**	**50**	**150**	**00**	**50**	**300**	**5**	**17**	**22**

Course Code	Course Type	Course Name	Teaching Scheme Hrs./week		Examination Scheme and Marks						Credits		
			L	P	CCE	ESE	TW	PR	OR	Total	L	P	Total
Semester IV													
SEM-651-CME	Seminar III	Seminar III	-	8	-	-	50	-	50	100	-	4	4
RPR-652-CME	Research Project	Project Stage-II	-	36	-	-	150	-	50	200	-	18	18
Total			**0**	**44**	**0**	**0**	**200**	**0**	**100**	**300**	**0**	**22**	**22**

CCE*: Comprehensive Continuous Evaluation

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PCC-501-CME	**Course Name: Advanced Machine Design**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04	4	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite: Students should have a solid foundation in mechanics of materials, linear algebra, and differential equations. Basic knowledge of structural analysis and heat transfer principles is recommended.

Course Objectives:

1. To understand stress-strain relations, stress functions, and failure criteria in materials.
2. To apply energy principles for analyzing structural deformation.
3. To study time-dependent failure phenomena under cyclic and sustained loads.
4. To introduce mechanical behavior and analysis techniques for composite materials.
5. To explore inelastic deformation including plasticity and time-dependent viscoelasticity.

Course Outcomes:

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

1. Analyze elastic behavior and predict material failure under different loading conditions.
2. Compute deflections and solve structural problems using energy-based methods.
3. Evaluate materials for fatigue and creep resistance in high-stress applications.
4. Design and analyze composite components for structural applications.
5. Model material behavior beyond elastic limits under various loading conditions.

Course Contents

Unit No: I	**Elasticity and Failure Theories**	**10 Hours**

Stress and strain at a point, principal stresses. Plane stress and plane strain conditions. Equilibrium and compatibility equations, generalized Hooke's law. Airy's stress function in rectangular and polar coordinates. Theories of failure: maximum principal stress, shear stress, Mohr's, distortion energy.

Unit No: II	**Energy Methods**	**10 Hours**

Strain energy from axial, torsional, shear, and bending loads. Castigliano's theorems and virtual work principle. Approximate methods: Rayleigh-Ritz and Galerkin's methods.

Unit No: III	**Fatigue, Fracture, and Creep**	**10 Hours**

Fatigue strength, influencing factors, cumulative damage. Effects of superimposed stresses and fatigue under complex loading. Brittle fracture mechanics and design. Creep behavior, exponential and sinh laws, stress relaxation.

Unit No: IV	**Composite Materials**	**08 Hours**

Composite types and structures, classical lamination theory. Elastic stress analysis, fatigue enhancement, and cut-out stress concentration. Stability of plates and shells, hybrid composites, applications.

Unit No: V	Theory of Plasticity and Viscoelasticity	10 Hours
Stress-strain curves, plastic flow, yield criteria (Von Mises, Tresca). Elasto-plastic bending and torsion, residual stresses. Viscoelastic models: Maxwell, Kelvin, and Maxwell-Kelvin combination.		

Reference Books

1. L S Srinath, **Advanced Solid Mechanics**, Tata McGraw-Hill.
2. S P Timoshenko, J N Goodier, **Theory of Elasticity (Third Edition)**, McGraw-Hill.
3. S.P.Timoshenko, "Theory of Plates & Shells", McGraw Hill, 1958.
4. M.F. Spotts & T.E. Shoup, **Design of Machine Elements**, Pearson Education.
5. Joseph E. Shigley & Chales R. Mischke **Mechanical Engineering Design**, McGraw Hill
6. George B. Dieter, **Engineering Design**, McGraw Hill.
7. Arhur H. Burr & John B. Chetham, **Mechanical Analysis & Design**, Prentice Hall India.
8. Robert C. Juvinall & Kurt, M. Marshel, **Fundamentals of Machine Component Design,** John Wiley & Sons.
9. Robert L. Norton, **Machine Design, An Integrated Approach**, Pearson Education
10. M. F. Spotts, **Mechanical Design Analysis,** Prentice-Hall.
11. D. Hull and T.W. Clyne, **An Introduction to Composite Materials,** Cambridge Solid State Science Series
12. Prager W., "Introduction to Plasticity", Oxford University Press, 1959.
13. Kachanov.L.M., "Foundations of Theory of Plasticity", North - Holland Publishing Co., 1971
14. Den Hartog, "Advanced Strength of Materials", McGraw Hill, 1952

Learning Resources

4. Links to online SWAYAM/NPTEL Courses

M1. https://nptel.ac.in/courses/112105125
M2. https://archive.nptel.ac.in/courses/112/105/112105124/
M3. https://ocw.mit.edu/courses/1-054-mechanics-and-design-of-concrete-structures-spring-2004/
M4. https://nptel.ac.in/courses/112103109

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PCC-502-CME	**Course Name: Computer Aided Design**

Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	: 04	4	CCE	: 50
Practical	: --		ESE	: 50
Tutorial	: --		PR	: --

Prerequisite: Students should have a fundamental understanding of engineering graphics, basic computer skills, and knowledge of geometry and mathematical concepts. Familiarity with manufacturing processes and design principles is also beneficial for effective learning of CAD/CAM tools and modeling techniques.

Course Objectives:

1. To understand CAD tool functionalities and wireframe modeling foundations.
2. To learn surface and solid modeling techniques essential for 3D design.
3. To understand advanced parametric surface modeling and manipulation.
4. To develop skills in drafting, assembly modeling, and advanced CAD techniques.
5. To understand collaborative engineering and effective data exchange methods.

Course Outcomes:

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

1. Ability to model 3D wireframe entities using parametric curve representations.
2. Develop accurate 3D solid models with appropriate geometric constraints.
3. Apply complex surface transformations and editing for versatile modeling.
4. Create detailed assemblies and realistic renderings using advanced CAD features.
5. Manage product data and facilitate CAD interoperability using standard data formats.

Course Contents

Unit No: I	**Introduction to CAD Tools and Wireframe Modeling**	**10 Hours**

CAD tools, types, evaluation criteria, CAD/CAM systems, graphics standards, software documentation, wireframe modeling, mathematical curve representations including Hermite cubic splines, Bezier curves, B-Splines, and NURBS.

Unit No: II	**Surface and Solid Modeling**	**10 Hours**

Mathematical and parametric surface representations (plane, ruled, revolution, tabulated), solid modeling methods including Boundary Representation (B-rep) and Constructive Solid Geometry (CSG), coordinate systems, modeling features, geometric constraints, and datum planes.

Unit No: III	**Parametric Synthetic Surfaces and Transformations**	**08 Hours**

Advanced surface modeling techniques such as Hermite Bicubic, Bezier, B-Spline, Coons, blending, and sculptured surfaces; surface manipulation including displaying, segmentation, trimming, intersection; 2D and 3D transformations including orthogonal and perspective views.

Unit No: IV	Drafting, Assembly, and Advanced Modeling Concepts	10 Hours
Drafting features and customization, 3D sketches, dimensioning, tolerances, annotations, assembly modeling with associative modeling, parametric design, parent-child relationships, computer animation concepts, advanced modeling including feature-based and behavioral modeling, top-down design, shading, rendering, and AI in CAD.		

Unit No: V	Collaborative Engineering and Data Exchange	10 Hours
Collaborative design principles, tools, Product Data Management (PDM), CAD/CAM data exchange requirements, standard data formats like IGES, STEP, ACIS, DXF, and data exchange architectures and implementation.		

Reference Books

1. Ibrahim Zeid, CAD/CAM Theory and Practice, McGraw Hill international.
2. P. N. Rao, CAD/CAM Tata McGraw Hill.
3. Foley, Van Dam, Feiner and Hughes, Computer Graphics Principles and Practice, second edition, Addison–Wesley, 2000.
4. Martenson, E. Micheal, Geometric Modelling, John Wiley & Sons, 1995.
5. Hill Jr, F.S., Computer Graphics using Open GL, Pearson Education, 2003.
6. Singeresu S. Rao, Engineering Optimization-Theory and Practice, New Age International Limited Publishers, 2000.
7. Johnson Ray, C. Optimum Design of Mechanical Elements, Wiley, John & Sons, 1981.
8. P. Radhakrishnan, S. Subramanyam, CAD/CAM/CIM, New Age International.
9. V. Ramamurti, Computer Aided Mechanical Design and Analysis, Tata Mc Graw Hill-1992.

Software Documentation, tutorials, manuals of following software:

1. UG/NX
2. Solid Works
3. CATIA
4. Autodesk Inventor Professional
5. AutoCAD
6. Open CASCADE
7. ANSYS Design Modeller
8. Pro/E

Learning Resources

4. Links to online SWAYAM/NPTEL Courses

M1. https://archive.nptel.ac.in/courses/112/102/112102101/

M2. https://archive.nptel.ac.in/courses/112/102/112102102/

M3. https://archive.nptel.ac.in/courses/112/104/112104031/

M4. https://archive.nptel.ac.in/courses/112/104/112104289/

M5. https://archive.nptel.ac.in/courses/112/102/112102101/

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PCC-503-CME	Course Name: Automated Manufacturing System Modeling

Teaching Scheme		Credits	Examination Scheme	
Theory	: 04	4	CCE	: 50
Practical	: --		ESE	: 50
Tutorial	: --		PR	: --

Prerequisite: Students should have a fundamental understanding of manufacturing processes, automation basics, and control systems. Knowledge of fluid power systems and basic mathematical modeling will support effective learning of automated manufacturing system concepts.

Course Objectives:

1. To introduce the principles, strategies, and elements of automation in production systems.
2. To explain components, classifications, and operation of automated manufacturing systems including FMS and cellular manufacturing.
3. To study pneumatic and hydraulic devices and design automation circuits using Boolean logic.
4. To introduce system modeling techniques and advanced tools like AI and neural networks in manufacturing automation.
5. To cover automated inspection systems, manufacturing support, and IoT-based data management in enterprises.

Course Outcomes:

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

1. Understand the fundamental concepts and levels of automation including PLCs.
2. Analyze manufacturing cells, flow lines, and transfer mechanisms in automated production.
3. Develop and interpret pneumatic circuits for automated manufacturing applications.
4. Apply mathematical models and AI concepts to enhance manufacturing automation.
5. Evaluate inspection techniques and integrate IoT concepts for manufacturing data optimization

Course Contents

Unit No: I	Introduction	10 Hours

Automation in Production System, Principles and Strategies of Automation, Basic Elements of an Automated System, Advanced Automation Functions, Levels of Automations, introduction to automation productivity, programmable logic controllers.

Unit No: II	Automated Manufacturing Systems	10 Hours

Components, Classification and Overview of Manufacturing Systems, Manufacturing Cells, GT and Cellular Manufacturing, FMS, FMS and its Planning and Implementation, Flow lines & Transfer Mechanisms, Fundamentals and Analysis of Transfer Lines, product design for automatic assembly.

Unit No: III	Pneumatic and hydraulic components and circuits	10 Hours

Boolean algebra, pneumatic sensors and amplifiers, jet destruction devices, logic devices, schimit triggering devices, developing pneumatic circuits for automatic die casting machine.

Unit No: IV	Manufacturing Plant Automation	08 Hours

Introduction, need for system Modeling, Building Mathematical Model of a manufacturing Plant, Modern Tools- Artificial neural networks in manufacturing automation, AI in manufacturing, Fuzzy decision and control, cellular manufacturing.

Unit No: V	Manufacturing Enterprise System	10 Hours
Inspection principles and strategies, automated inspection, contact Vs non contact, CMM. Manufacturing support systems. Gathering the data, user data requirement, data formats, data optimization and security, Concept Internet of things (IOT) in manufacturing system		

Reference Books
1. Automation, **production systems and computer integrated manufacturing**/ Mikell.P Groover/PHI/3rd edition/2012, 2. Narahari Y., Viswanadham N., **Performance Modelling Of Automated Manufacturing Systems**, Prentice-Hall India. 3. Alan A. Desrochers, **Modelling and Control of Automated Manufacturing Systems** IEEE Computer Society Press 1990. 4. Paul M. Stanfield, **Performance Modelling of Automated Manufacturing Systems**, Institute of Industrial Engineers, Inc. 5. **Industrial Automation** : W.P. David, John Wiley and Sons. 6. **An Introduction to Automated Process Planning Systems**, Tiess Chiu Chang & Richard A. Wysk 7. **Anatomy of Automation**, Amber G.H & P. S. Amber, Prentice Hall.

Learning Resources
4. Links to online SWAYAM/NPTEL Courses
M1. https://archive.nptel.ac.in/courses/110/105/110105155/ M2. https://archive.nptel.ac.in/courses/112/103/112103293/ M3. https://nptel.ac.in/courses/112102011

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PCC-504-CME	**Course Name: Finite Element Method**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04	4	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite:

Course Objectives:

1. To introduce the fundamentals of FEA and its role in design and simulation.
2. To develop the finite element formulations for truss and beam elements using interpolation and shape functions.
3. To explain the concept of isoperimetric formulation and numerical integration for 2D and 3D problems.
4. To introduce finite element techniques for dynamic structural analysis including modal and time-domain methods.
5. To apply FEM to solve problems in heat transfer and fluid flow.

Course Outcomes:

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

1. Understand the basic FEM process, including discretization and analysis of 1D element under mechanical and thermal loads.
2. Construct element matrices and perform stress analysis for truss and beam structures.
3. Apply isoperimetric elements in complex geometries and compute accurate stress results.
4. Analyze dynamic behavior using mass and damping matrices and perform modal and time-history analysis.
5. Formulate and solve thermal and fluid-structure interaction problems using FEM.

Course Contents

Unit No: I	**Introduction to Finite Element Analysis**	**10 Hours**

Relevance of FEA in design, modeling and discretization, interpolation methods, elements, nodes, and degrees of freedom. Applications of FEA in structural and thermal problems. Analysis of 1D elements like bar and beam, stiffness matrices, boundary conditions, and load applications.

Unit No: II	**Truss and Beam Elements**	**10 Hours**

Shape functions and interpolation techniques for truss and beam elements. Element matrix formulation for triangular, rectangular, and solid elements including higher-order forms. Development of equations, nodal loads, and stress calculation procedures.

Unit No: III	**Isoperimetric Elements**	**10 Hours**

Formulation of bilinear and quadratic quadrilateral, and hexahedral elements. Numerical integration, quadrature techniques, and static condensation. Stress evaluation and examples of 2D and 3D FEM applications.

Unit No: IV	Structural Dynamics Applications	08 Hours
Static analysis of trusses, plates, and solids of revolution. Dynamic analysis: mass and damping matrices, natural frequencies, mode shapes. Modal methods, Ritz vectors, time integration, and response spectrum analysis.		

Unit No: V	Heat Transfer and Fluid Mechanics Applications	10 Hours
FEM formulation for steady and transient thermal analysis. Nonlinear problem reduction and acoustic mode analysis. Fluid-structure interaction, plane incompressible and rotational flow modelling.		

Reference Books

1. R. D. Cook. **Concepts and applications of finite element analysis**. John Wiley & Sons, 2007.
2. D. L. Logan. **A first course in the finite element method**. Cengage Learning, 2016.
3. J. N. Reddy. **An introduction to the finite element method**, Vol. 1221, New York: McGraw-Hill, 2004.
4. T. Chandrupatla, A. Belegundu. **Introduction to finite elements in engineering**. Cambridge University Press, 2021.
5. O. C. Zienkiewicz, R. L. Taylor, J. Z. Zhu. **The finite element method: its basis and fundamentals**. Elsevier, 2005.

Learning Resources

4. Links to online SWAYAM/NPTEL Courses

M1. https://archive.nptel.ac.in/courses/112/104/112104193/

M2. https://archive.nptel.ac.in/courses/112/105/112105308/

M3. https://archive.nptel.ac.in/courses/105/105/105105041/

M4. https://archive.nptel.ac.in/courses/105/106/105106151/

M5. https://archive.nptel.ac.in/courses/105/101/105101006/

M6. https://archive.nptel.ac.in/courses/105/101/105101209/

M7. https://archive.nptel.ac.in/courses/105/106/105106051/

M8. https://archive.nptel.ac.in/courses/112/104/112104302/

M9. https://archive.nptel.ac.in/courses/112/104/112104030/

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PCC-505-CME	**Course Name: Lab Practice –I**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : --		CCE :
Practical : 4	2	ESE :
Tutorial : --		OR : 25 TW : 25

Prerequisite:

- Basic knowledge of mechanical design engineering fundamentals.
- Awareness of core subjects such as Thermodynamics, Fluid Mechanics, Strength of Materials, and Manufacturing Processes
- Ability to read and interpret engineering drawings
- Exposure to CAD software and basic programming skills is desirable

Course Objectives:

1. To develop hands-on skills by applying theoretical knowledge in practical applications
2. To expose students to industrial practices and modern manufacturing tools
3. To strengthen the understanding of engineering processes through laboratory work and project-based learning
4. To encourage problem-solving, teamwork, and communication skills through multidisciplinary mini-projects
5. To enhance student readiness for industry and real-world technical challenges

Course Outcomes:

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

1. Apply theoretical concepts in practical laboratory settings across multiple domains of mechanical engineering.
2. Identify, analyze, and solve basic engineering problems through experimental approaches.
3. Use engineering tools, equipment, and software to perform tests, collect data, and interpret results.
4. Collaborate effectively in teams and develop solutions to multidisciplinary engineering problems. Also prepare and present technical reports, project documentation, and oral presentations professionally
5. Demonstrate readiness for industrial training or internships through improved technical and soft skills

List of Experiments

Perform **all** experiments from following list:

1. Surface Modelling of Mechanical Components.
2. Drafting and modeling of machine parts with assembly using suitable software.
3. Assignment on design for fatigue, fracture and creep.
4. Assignment on Plasticity.
5. Case study on failure analysis of mechanical components.

Guidelines for Instructor's Manual

Course Planning:

Prepare a week-wise schedule covering all lab activities.
Align experiments and mini-projects with the core subjects of the semester.

Lab Preparation:
Ensure all equipment, tools, and materials are available and functional before each session.

Provide safety instructions and ensure proper usage of laboratory instruments.
Instructional Support:
Brief students before every experiment, explaining objectives, procedure, expected outcomes, and safety precautions.
Encourage students to discuss real-world applications of each lab activity.

Guidelines for Students Lab Manual

Each lab report should include: Title of experiment, Aim, Apparatus/tools used, Theory/concept, Procedure, Observations/data, Calculations

Guidelines for Lab assessment

Use a predefined rubric for evaluating lab performance, mini-project work, viva, attendance, and journal completion.
Provide regular feedback for continuous improvement.

Guidelines for Lab conduction

Solid modelling, assembly modelling, drafting assignments using software like UNIGRAPHICS, Solid Works, CATIA, Pro/Engineer, I-DEAS, Autodesk Inventor, etc and study of the various facilities in these software's. Finite Element Analysis Assignments using software's like ANSYS, Hyper Mesh Ls-Dyna, Abacus etc. (Failure related)

Lab Setup and Safety:

Ensure all machines and tools are safe, calibrated, and accessible.

Display safety rules and emergency contact numbers prominently.

Session Conduct:

Begin with a short briefing about the objective and theoretical background.

Monitor students as they perform the experiment; intervene when necessary.

Time Management:

Allocate time effectively between demonstration, hands-on work, and discussion.

Encourage timely submission of observation and results.

Team Activities:

Promote group activities during the mini-projects to build teamwork skills.

Ensure equal participation from all group members.

Learning Resources

1. Test Books

1. R.K. Rajput "Thermal Engineering", Laxmi Publications
2. R.K. Bansal "Strength of Materials", Laxmi Publications
3. R.K. Bansal "Fluid Mechanics and Hydraulic Machines", Laxmi Publications
4. P.N. Rao "Manufacturing Technology – I & II", McGraw Hill Education

2. Reference Books

R1. A.E. Clayton and N. N. Hancock, "Performance and Design of Direct Current
R2. T.D. Eastop and A. McConkey "Applied Thermodynamics for Engineering Technologists", Pearson Education
R3. Egor P. Popov "Engineering Mechanics of Solids", Pearson Education
R4. S.K. Som & G. Biswas "Introduction to Fluid Mechanics and Fluid Machines", McGraw Hill
R5. Kalpakjian and Schmid "Manufacturing Processes", Pearson Education

3. e-Books
1. Engineering Thermodynamics by Yunus A. Cengel. Available on: McGraw Hill eBook Store **2.** Strength of Materials by Ferdinand P. Beer & E. Russell Johnston. Available on: McGraw Hill eBook Store **3.** Fluid Mechanics Fundamentals and Applications by Yunus A. Cengel. Available on: McGraw Hill eBook Store **4.** Fundamentals of Modern Manufacturing by Mikell P. Groover. Available on: Wiley Online Library
4. Links to online SWAYAM/NPTEL Courses
M1. https://onlinecourses.nptel.ac.in/noc23_me140/preview M2. https://onlinecourses.nptel.ac.in/noc25_me119/preview M3. https://onlinecourses.nptel.ac.in/noc25_me148/preview

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PEC-521A-CME	**Course Name: Product Design and Development**

Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	: 03	3	CCE	: 50
Practical	: --		ESE	: 50
Tutorial	: --		PR	: --

Prerequisite: Basic knowledge of Engineering Graphics and Design, Understanding of Materials and Manufacturing Processes, Fundamentals of Engineering Mechanics.

Course Objectives:

1. To introduce the foundational concepts of product design and development.
2. To equip students with tools and methods to identify, analyze, and translate customer needs into technical specifications.
3. To foster creative thinking and equip students with structured techniques for generating and analyzing product design concepts.
4. To develop decision-making skills for evaluating design alternatives and understanding the structure and architecture of products.
5. To integrate human factors, environmental considerations, and cost evaluation in product design.

Course Outcomes:

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

1. Understand the structured process of product design and development and market planning.
2. Gather and analyze customer needs to define technical design specifications.
3. Apply creative and structured methods for concept generation and development.
4. Use decision-making techniques to evaluate design alternatives and develop product architecture.
5. Integrate human factors and cost considerations into the design process.

Course Contents

Unit No: I	**Product Development Fundamentals and Market Planning**	**07 Hours**

Need for product development, types of engineering design, design process, product lifecycle relevance, codes and standards, societal aspects. Product development phases, planning, market identification, segmentation, and market research.

Unit No: II	**Customer Needs and Specification Development**	**07 Hours**

Voice of customer, human needs hierarchy, need gathering methods, affinity diagrams, prioritizing needs, competitive benchmarking, QFD, House of Quality, product design specification, case study.

Unit No: III	**Creativity and Concept Generation**	**07 Hours**

Creative thinking and problem-solving, idea generation techniques, functional and physical decomposition, morphological methods, TRIZ, axiomatic design.

Unit No: IV	**Decision Making and Product Architecture**	**07 Hours**

Decision and utility theory, decision trees, Pugh method, weighted matrix, AHP. Embodiment design, product architecture, modularity, and development steps.

Unit No: V	**Industrial Design and Costing**	**08 Hours**

Human-centred design, ergonomics, serviceability, environmental design, prototyping, cost types, activity-based costing, cost estimation, value analysis.

List of Practicals

1. Market Research and Product Planning: Conduct a small market survey to identify product needs and define a target market segment.
2. Customer Needs and QFD Exercise: Identify customer needs for a chosen product and prepare a House of Quality (QFD matrix).
3. Creative Concept Generation: Use brainstorming, morphological charts, and TRIZ to generate multiple product design concepts.
4. Design Evaluation and Selection: Apply Pugh's method and AHP to evaluate and select the best concept among alternatives.
5. Prototype Design and Cost Estimation: Develop a basic prototype and estimate its manufacturing cost using activity-based costing.

Reference Books

1. K. T. Ulrich and S. D. Eppinger. Product Design and Development, McGraw-Hill Education, 2016
2. C. L. Dym, P. Little and E. Orwin. Engineering Design: A Project-Based Introduction, 4th Edition, John Wiley & Sons Inc., 2013.
3. G. E. Dieter and L. C. Schmidt. Engineering Design, McGraw-Hill International Edition, 2013.
4. Jamnia. Introduction to Product Design and Development for Engineers, CRC Press, 2018.
5. K. Prashant. Product Design: Creativity, Concepts and Usability, PHI Learning Private Limited, 2012.

Savitribai Phule Pune University Board: Mechanical Engineering ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)		
Course Code: PEC-521B-CME	**Course Name: Rapid Prototyping and Tooling**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03	3	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite: Basics of CAD/CAM, Engineering Materials and Manufacturing Processes, Computer-Aided Design and 3D Modelling.

Course Objectives:

1. To understand the basics, evolution, and importance of rapid prototyping in modern product development.
2. To provide knowledge on data capture, STL file generation, and slicing for RP.
3. To introduce RP methods based on liquid and powder feed stocks with focus on material compatibility and applications.
4. To understand solid-based RP methods and essential toolpath planning strategies.
5. To provide insights into the use of RP for tooling and direct manufacturing applications.

Course Outcomes:

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

1. Explain the role and process of rapid prototyping in product development.
2. Prepare and manipulate CAD models and data for RP processes.
3. Differentiate between various RP technologies and select suitable materials and methods.
4. Generate optimized slicing and tool paths for additive manufacturing.
5. Apply RP concepts in rapid tooling and evaluate its relevance in manufacturing.

Course Contents

Unit No: I	**Introduction to Rapid Prototyping**	**07 Hours**

Overview of CAD/CAM integration, evolution of RP, time compression technologies, RP in product development, and process chain for rapid prototyping.

Unit No: II	**Reverse Engineering and Data Preparation**	**07 Hours**

Reverse engineering methods, digitizing techniques (mechanical, optical, CT scanning), surface data processing, STL file format and handling, file repair, support structures, part orientation, and model slicing.

Unit No: III	**Liquid-Based and Powder-Based RP Processes**	**07 Hours**

Working principles of stereolithography, photo polymerization, mask projection, two-photon techniques. Powder-based processes: SLS, LENS, EBM, binder jetting – materials, fusion, and recycling.

Unit No: IV	**Solid-Based RP and Tool Path Generation**	**07 Hours**

Fused Deposition Modelling (FDM), bio extrusion, Laminated Object Manufacturing (LOM), wire & arc-based RP, slicing and contouring, adaptive layer thickness, tool path planning.

Unit No: V	**Rapid Tooling and Manufacturing**	**08 Hours**

Types of rapid tooling: indirect and direct methods for soft/bridge and production tooling. RP for pattern generation. Introduction to rapid manufacturing methods and their limitations.

List of Practicals

1. STL File Generation and Repair: Convert CAD model to STL format and perform basic repair operations.
2. Reverse Engineering using 3D Scanner: Digitize a physical component and reconstruct the CAD model.
3. Slicing and Tool Path Simulation: Use slicing software to generate layers and simulate tool paths for an RP model.
4. Hands-on with FDM 3D Printing: Print a part using FDM printer and analyze part orientation and support structure.
5. Case Study on Rapid Tooling Application: Study an industrial case of direct or indirect tooling using RP.

Reference Books

1. D. Gibson, Rosen, B. Stucker. Additive Manufacturing Technologies, Springer Publisher,2010.
2. C. K. Chua, K. F. Leong, C. S. Lim. Rapid Prototyping – Principles and Applications, World Scientific, 3rd Edition, 2010.
3. K. V. Patri and M. Weiyin. Rapid Prototyping: Laser-based and Other Technologies, Springer Publisher, 2004.
4. R. Noorani. 3D Printing Technology, Applications and Selection, CRC Press, 2017.
5. M. W. M. Cunico. 3D Printers and Additive Manufacturing: The Rise of The Industry 4.0, Concept 3D, 2019.

Savitribai Phule Pune University Board: Mechanical Engineering ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)	
Course Code: PEC-521C-CME	**Course Name: Computer Aided Tool Design**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03	3	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite: Basics of Manufacturing Processes, Engineering Graphics and CAD, Knowledge of Cutting Tools and Jigs & Fixtures.

Course Objectives:

1. To understand the foundational concepts in tool design along with suitable tool materials.
2. To impart knowledge on the design of press tools and gages with emphasis on function, accuracy, and manufacturing feasibility.
3. To learn the systematic design of drill jigs with integration of CAD in design.
4. To develop competence in designing various types of fixtures with a focus on automation and cost-efficiency using CAD tools.
5. To apply principles of mould design using CAD software for plastic processing applications.

Course Outcomes:

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

1. Apply systematic design procedures for industrial tools using CAD techniques.
2. Select appropriate materials and manufacturing methods for tool production.
3. Design press tools, gages, and jigs considering function and manufacturability.
4. Create effective fixture designs suitable for various machining operations.
5. Integrate computer-aided methods for designing moulds and tooling components.

Course Contents

Unit No: I	**Introduction to Tool Design & Tooling Materials**	**07 Hours**

Overview of tool design methods; Design procedure; Identifying and analyzing tool design problems; Needs analysis; Drafting and CAD techniques for tooling drawings. Tooling material properties; Classification of metal cutting tools—single-point, multipoint, drills, reamers, taps; Criteria for selecting carbide tools and determining insert thickness; Overview of heat treatments.

Unit No: II	Punch, Die, and Gage Design	**07 Hours**

Punch and die manufacturing techniques; Fundamentals of press tool design—blanking, piercing, pilots, strippers, pressure pads, presswork materials, and strip layout. Types of dies for bending, forming, and drawing; Fixed and indicating gages, automatic gages; Gage tolerances and material selection.

Unit No: III	Design of Drill Jigs	**07 Hours**

Locating principles and devices; Clamping principles and methods; Design and types of drill jigs; Drill bushings, chip control in drilling; Modern jig design with CAD tools.

Unit No: IV	Design of Fixtures	**07 Hours**

Introduction to fixtures and their economic importance; Types—vice, milling, boring, broaching, lathe, grinding fixtures; Elements of die construction; Computer-aided fixture design.		
Unit No: V	Design of Moulding Dies	**08 Hours**
Basics of injection and compression moulding processes; Parting line and air vent design; Ejection systems; CAD-based design techniques for moulding dies.		

List of Practicals

1. Design of Blanking and Piercing Die using CAD software.
2. 3D Modeling of Drill Jig with clamping and locating elements.
3. Fixture Design for Milling Operation with assembly drawings.
4. Gage Design Practice – Creating a fixed gage with tolerance analysis.
5. Injection Mould Design – CAD modeling including parting line and ejection system.

Reference Books

1. C. Donaldson, H. L. George, V. C. Goold. Tool Design, Tata McGraw Hill Publishing Company Ltd., 36th Reprint 2006.
2. P. H. Joshi. Tooling Data, Wheeler Publishing, 2000.
3. P. C. Sharma. Machine Tool and Tool Design, S Chand Company. 2004.
4. J.Y.H. Fuh. Computer aided Injection mold design and manufacture, CRC Press 2018.
5. J. R. Paquin, R. E. Crowley. Die design fundamentals, Ind. Press Inc., New York, 1987.

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PEC-521D-CME	**Course Name: Optimization Techniques**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03	3	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite: Basic knowledge of Engineering Mathematics, Fundamentals of Programming (preferably MATLAB/Python), Understanding of Linear Algebra and Calculus.

Course Objectives:

1. To introduce the fundamentals of optimization and linear programming techniques with various solution strategies.
2. To analyze the robustness of solutions and understand duality concepts in optimization.
3. To develop the ability to formulate and solve specialized LP problems relevant to logistics and scheduling.
4. To explore nonlinear optimization models and solve them using mathematical and computational approaches.
5. To apply modern heuristic optimization algorithms for solving complex engineering problems.

Course Outcomes:

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

1. Formulate and solve optimization problems using classical methods.
2. Perform sensitivity and post-optimality analysis to evaluate robustness.
3. Model and solve transportation, TSP, and integer programming problems.
4. Solve nonlinear problems using analytical and computational methods.
5. Apply evolutionary algorithms to multi-objective and real-life engineering problems.

Course Contents

Unit No: I	**Introduction to Optimization and Linear Programming**	**07 Hours**

Basics of optimization; Formulating linear programming (LP) problems; Graphical solution method; Simplex algorithm; Handling special cases in simplex.

Unit No: II	**Sensitivity Analysis and Duality**	**07 Hours**

Post-optimality and sensitivity analysis; Impact of changes in resources and objectives on solution feasibility and optimality; Concept of duality; Dual simplex and generalized simplex methods.

Unit No: III	**Special Linear Programming Models**	**07 Hours**

Modeling and solving transportation and transshipment problems; Travelling Salesman Problem (TSP); Basics of Integer Programming and solution strategies.

Unit No: IV	**Nonlinear Programming & Computational Methods**	**07 Hours**

Convex functions and regions; Necessary and sufficient conditions; Lagrangian method and KKT conditions; Solving nonlinear optimization problems using software tools.

Unit No: V	Evolutionary Algorithms and Multi-objective Optimization	08 Hours
Introduction to evolutionary algorithms; Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Differential Evolution (DE), Tabu Search, Simulated Annealing; Basics of multi-objective optimization; Solving real-world problems using programming tools.		

List of Practicals

1. Solving Linear Programming Problem using Simplex Method (MATLAB/Python).
2. Modeling and solving Transportation Problem using software tool.
3. Nonlinear Optimization using Lagrangian and KKT Conditions with symbolic math.
4. Implementing Genetic Algorithm for Engineering Optimization.
5. Solving Multi-objective Optimization using Particle Swarm Optimization.

Text Books

1. S. S. Rao, **Engineering Optimization Theory and Practice**, New age international (P) Ltd., reprint 2003
2. Kalyanmoy Deb, **Optimization for Engineering Design**, PHI, New Delhi, 2005
3. J. S. Arora, **Introduction to Optimum Design**, McGraw Hill, New York, 1989.

Reference Books

1. S. S. Stricker, **Optimizing Performance of Energy Systems,** Battelle Press, New York, 1985.
2. R.C. Johnson, **Optimum Design of Mechanical Elements**, Willey, New York, 1980.
3. L.C.W. Dixon, **Non-Linear Optimization - Theory and Algorithms**, Birkhauser, Boston, 1980.
4. R.J. Duffin, E.L. Peterson and C. Zener, **Geometric Programming-Theory and Applications**, Willey, New York, 1967
5. G.B. Dantzig **Linear Programming and Extensions Princeton University Press**, Princeton, N. J. 1963.
6. R. Bellman, **Dynamic Programming** Princeton University Press, Princeton, N.J. 1957.

Savitribai Phule Pune University Board: Mechanical Engineering ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)		
Course Code: PEC-522A-CME	**Course Name: Elective I Fieldwork Assignments**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : --		CCE : --
Practical : 02	1	ESE : --
Tutorial : --		TW : 25 OR : 25
Course Name: Product Design and Development Fieldwork Assignments		
Prerequisite: Basic knowledge of Engineering Graphics and Design, Understanding of Materials and Manufacturing Processes, Fundamentals of Engineering Mechanics.		

Product Design and Development field work file shall consist of the following assignments

1. Market Research and Product Planning: Conduct a small market survey to identify product needs and define a target market segment.

   Objective: To conduct a market survey for identifying product needs and defining a target market segment.

2. Customer Needs and QFD Exercise: Identify customer needs for a chosen product and prepare a House of Quality (QFD matrix).

   Objective: To identify customer needs and translate them into design requirements using a QFD matrix.

3. Creative Concept Generation: Use brainstorming, morphological charts, and TRIZ to generate multiple product design concepts.
   Objective: To generate multiple innovative product design concepts using brainstorming, morphological charts, and TRIZ.
4. Design Evaluation and Selection: Apply Pugh's method and AHP to evaluate and select the best concept among alternatives.

   Objective: To evaluate and select the best product concept using Pugh's method and AHP.

5. Prototype Design and Cost Estimation: Develop a basic prototype and estimate its manufacturing cost using activity-based costing.

   Objective: To design a basic prototype and estimate its manufacturing cost using activity-based costing.

Reference Books

6. K. T. Ulrich and S. D. Eppinger. Product Design and Development, McGraw-Hill Education, 2016
7. C. L. Dym, P. Little and E. Orwin. Engineering Design: A Project-Based Introduction, 4th Edition, John Wiley & Sons Inc., 2013.
8. G. E. Dieter and L. C. Schmidt. Engineering Design, McGraw-Hill International Edition, 2013.
9. Jamnia. Introduction to Product Design and Development for Engineers, CRC Press, 2018.
10. K. Prashant. Product Design: Creativity, Concepts and Usability, PHI Learning Private Limited, 2012.

Savitribai Phule Pune University Board: Mechanical Engineering ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)			
Course Code: PEC-522B-CME	**Course Name: Elective I Fieldwork Assignments**		
Teaching Scheme	**Credits**	**Examination Scheme**	
Theory : --		CCE : --	
Practical : 02	1	ESE : --	
Tutorial : --		TW : 25	OR : 25
Course Name: Rapid Prototyping and Tooling Fieldwork Assignments			
Prerequisite: Basics of CAD/CAM, Engineering Materials and Manufacturing Processes, Computer-Aided Design and 3D Modelling.			

Rapid Prototyping and Tooling field work file shall consist of the following assignments

1. STL File Generation and Repair: Convert CAD model to STL format and perform basic repair operations.

   Objective: To convert a CAD model into STL format and perform basic repair operations for error-free prototyping.
2. Reverse Engineering using 3D Scanner: Digitize a physical component and reconstruct the CAD model.

   Objective: To digitize a physical component using 3D scanning and reconstruct its CAD model accurately.
3. Slicing and Tool Path Simulation: Use slicing software to generate layers and simulate tool paths for an RP model.

   Objective: To generate slice layers and simulate tool paths for an RP model using slicing software.
4. Hands-on with FDM 3D Printing: Print a part using FDM printer and analyze part orientation and support structure.

   Objective: To print a part using an FDM printer and analyze the effects of orientation and support structures.
5. Case Study on Rapid Tooling Application: Study an industrial case of direct or indirect tooling using RP.

   Objective: To study an industrial case of direct or indirect tooling applications using rapid prototyping.

Reference Books

1. D. Gibson, Rosen, B. Stucker. Additive Manufacturing Technologies, Springer Publisher,2010.
2. C. K. Chua, K. F. Leong, C. S. Lim. Rapid Prototyping – Principles and Applications, World Scientific, 3rd Edition, 2010.
3. K. V. Patri and M. Weiyin. Rapid Prototyping: Laser-based and Other Technologies, Springer Publisher, 2004.
4. R. Noorani. 3D Printing Technology, Applications and Selection, CRC Press, 2017.
5. M. W. M. Cunico. 3D Printers and Additive Manufacturing: The Rise of The Industry 4.0, Concept 3D, 2019.

Savitribai Phule Pune University Board: Mechanical Engineering ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)		
Course Code: PEC-522C-CME	**Course Name: Elective I Fieldwork Assignments**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : --		CCE : --
Practical : 02	1	ESE : --
Tutorial : --		TW : 25 OR : 25
Course Name: Computer Aided Tool Design Fieldwork Assignments		
Prerequisite: Basics of Manufacturing Processes, Engineering Graphics and CAD, Knowledge of Cutting Tools and Jigs & Fixtures.		

Computer Aided Tool Design field work file shall consist of the following assignments

1. Design of Blanking and Piercing Die using CAD software.

   Objective: To design a blanking and piercing die using CAD tools with proper dimensions and features.

2. 3D Modeling of Drill Jig with clamping and locating elements.

   Objective: To create a 3D CAD model of a drill jig incorporating clamping and locating elements.

3. Fixture Design for Milling Operation with assembly drawings.

   Objective: To design a milling fixture with complete assembly drawings using CAD software.

4. Gage Design Practice – Creating a fixed gage with tolerance analysis.

   Objective: To design a fixed gage and perform tolerance analysis for dimensional accuracy.

5. Injection Mould Design – CAD modeling including parting line and ejection system.

   Objective: To develop a CAD model of an injection mould incorporating parting line and ejection system

Reference Books

1. C. Donaldson, H. L. George, V. C. Goold. Tool Design, Tata McGraw Hill Publishing Company Ltd., 36th Reprint 2006.
2. P. H. Joshi. Tooling Data, Wheeler Publishing, 2000.
3. P. C. Sharma. Machine Tool and Tool Design, S Chand Company. 2004.
4. J.Y.H. Fuh. Computer aided Injection mold design and manufacture, CRC Press 2018.
5. J. R. Paquin, R. E. Crowley. Die design fundamentals, Ind. Press Inc., New York, 1987.

Savitribai Phule Pune University Board: Mechanical Engineering ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)		
Course Code: PEC-522D-CME	**Course Name: Elective I Fieldwork Assignments**	
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : --		CCE : --
Practical : 02	1	ESE : --
Tutorial : --		TW : 25 OR : 25
Course Name: Optimization Techniques Fieldwork Assignments		
Prerequisite: Basic knowledge of Engineering Mathematics, Fundamentals of Programming (preferably MATLAB/Python), Understanding of Linear Algebra and Calculus.		

Optimization Techniques field work file shall consist of the following assignments

1. Solving Linear Programming Problem using Simplex Method (MATLAB/Python).

   Objective: To solve linear programming problems using the simplex method with MATLAB/Python implementation.
2. Modeling and solving Transportation Problem using software tool**.**

   Objective: To model and solve transportation problems efficiently using an optimization software tool.
3. Nonlinear Optimization using Lagrangian and KKT Conditions with symbolic math.

   Objective: To apply Lagrangian and KKT conditions for solving nonlinear optimization problems using symbolic math.
4. Implementing Genetic Algorithm for Engineering Optimization**.**

   Objective: To implement and apply genetic algorithms for solving engineering optimization problems.
5. Solving Multi-objective Optimization using Particle Swarm Optimization**.**

   Objective: To solve multi-objective optimization problems using the particle swarm optimization technique.

Text Books

1. S. S. Rao, **Engineering Optimization Theory and Practice**, New age international (P) Ltd., reprint 2003
2. Kalyanmoy Deb, **Optimization for Engineering Design**, PHI, New Delhi, 2005
3. J. S. Arora, **Introduction to Optimum Design**, McGraw Hill, New York, 1989.

Reference Books

1. S. S. Stricker, **Optimizing Performance of Energy Systems,** Battelle Press, New York, 1985.
2. R.C. Johnson, **Optimum Design of Mechanical Elements**, Willey, New York, 1980.
3. L.C.W. Dixon, **Non-Linear Optimization - Theory and Algorithms**, Birkhauser, Boston, 1980.
4. R.J. Duffin, E.L. Peterson and C. Zener, **Geometric Programming-Theory and Applications**, Willey, New York, 1967

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PCC-551-CME	**Course Name: Computer Integrated Manufacturing**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04	4	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite: Students are expected to have foundational knowledge of CAD/CAM technologies, CNC operations, and core manufacturing processes. An understanding of automation systems and production planning concepts will further support learning in CIM applications.

Course Objectives:

1. To introduce the fundamentals and structure of CIM and its technological framework.
2. To provide insights into managing manufacturing data within CIM environments.
3. To explore automation through cellular layouts and integration with flexible manufacturing.
4. To enable understanding of real-time planning and control in integrated manufacturing.
5. To introduce emerging technologies and philosophies shaping future manufacturing.

Course Outcomes:

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

1. Define CIM architecture and identify its hardware, software, and networking components.
2. Describe and differentiate database models and tools like PDM and EDM in CIM.
3. Explain the configuration and benefits of flexible and cell-based manufacturing systems.
4. Apply planning techniques and control strategies for synchronized CIM operations.
5. Evaluate the impact of web integration and lean practices on productivity and flexibility.

Course Contents

Unit No: I	**Concept of CIM**	**10 Hours**

Introduction to CIM, Types of Manufacturing, CIM hardware and software, Elements of CIM, Product development through CIM Design Activities in a networked environment, networking in a manufacturing company, hardware elements of networking.

Unit No: II	**CIM Database**	**10 Hours**

Introduction, Database requirements of CIM, Database, Database management, Database Models, EDM, Product Data Management (PDM), Advantage of PDM. , Collaboration Engineering.

Unit No: III	**Work Cell & Flexible Manufacturing System**	**10 Hours**

Manufacturing cell, Group Technology, Cellular Manufacturing. DNC system and transfer of program from PC to machine. Introduction to FMS, Manufacturing integration model, flexible manufacturing strategy, Components of Flexible Manufacturing-Pallets and fixtures, machining centers, inspection equipment, material handling stations, storage system, In-process storage, manually operated stations, allied operation centres.

Unit No: IV	**Integrative Manufacturing Planning and Control**	**10 Hours**

Role of integrative manufacturing in CAD/CAM integration, Over view of production control - Forecasting, Master production schedule, Capacity planning, M.R.P., Order release, Shop-floor control,

Quality assurance, Planning and control systems, Cellular manufacturing, JIT manufacturing philosophy.		
Unit No: V	**Web-Based and Lean Manufacturing Systems**	**08 Hours**
Integrating process with web, Process management and control through web, Applications of web based manufacturing, casting, machining, forming & forging. Lean Manufacturing: Definition, Principles of Lean Manufacturing, Characteristics of Lean Manufacturing, Value of Product, Continuous Improvement, Four Functions of Lean Production, Performance Measures.		

Reference Books

1. Paul G. Ranky, **The Design and Operation of FMS**, I.F.S. Publications 1983
2. Harrington J, **Computer Integrated Manufacturing** Krieger Publications 1979
3. Richard N. Shover, **An Analysis of CAD/CAM Application with Introduction to C.I.M.** Prentice hall
4. David Bedworth et. al., **Computer Integrated Design and Manufacturing** McGraw hill 1991
5. Scolz B. Reiter **C.I.M Interfaces** Chapman & Hall 1992
6. David L. Goetsch, **Fundamental of CIM Technology**, Delmar Publication 1988
7. Groover, M.P., (2004), **Automation, Production Systems & Computer Integrated Manufacturing** second edition, Pearson Education ISBN: 81-7808-511-9
8. Groover, Weiss, Nagel, Audrey, **Industrial Robotics-Technology, Programming and Applications**, McGraw Hill.
9. Nanua Singh, **Systems Approach to Computer Integrated Design and Manufacturing**, John Wiley Publications.
10. Alavudeen, Venkateshwaran, **Computer Integrated Manufacturing**, Prentice-Hall India

Learning Resources

4. Links to online SWAYAM/NPTEL Courses

M1. https://archive.nptel.ac.in/courses/112/104/112104289/

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PCC-552-CME	**Course Name: Industrial Product Design & Product Life Cycle Management**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 04	4	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite: Students should have a basic understanding of product design, manufacturing processes, and engineering economics. Familiarity with CAD tools and fundamental principles of product development will facilitate comprehension of advanced product lifecycle and data management concepts.

Course Objectives:

1. To introduce modern product development processes including design creativity, reverse engineering, and concurrent design.
2. To analyze economic factors influencing design and methods for generating innovative product concepts.
3. To study product teardown analysis and apply value engineering principles in product design.
4. To explain the concept, components, and significance of PLM and its integration with CAD and ERP systems.
5. To describe PDM systems, architectures, and their role in collaborative product development.

Course Outcomes:

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

1. Understand phases of product design and apply modern development techniques like QFD and rapid prototyping.
2. Evaluate customer requirements and apply systematic concept generation and selection methods.
3. Perform product benchmarking and implement value analysis for design optimization.
4. Understand PLM workflows and tools to manage product lifecycle effectively.
5. Manage engineering data, version control, and configuration management using PDM tools.

Course Contents

Unit No: I	**Product Development**	**10 Hours**

Design creativity-innovations in design alternatives. Modern product development process, reverse engineering and redesign product development process, scoping product development – S-curve, new product development.

The phases of product design process, Modern approaches to product design: Concurrent Design, Quality Function Development (QFD), Rapid Prototyping.

Unit No: II	**Understanding Customer Needs & Generating Concepts**	**10 Hours**

Economic factors influencing design, product value, safety, reliability & environmental considerations, economic analysis, break even analysis, profit & competitiveness, economics of new product design. FAST method, establishing system functionality.

GENERATING CONCEPTS: Information gathering, brain ball, C-sketch/6-3-5 method, morphological analysis, concept selection, technical feasibility, ranking, measurement theory, DFMA, design for robustness.

Unit No: III	**Product Tear Down and Value engineering**	**10 Hours**

Tear down method, post teardown report, benchmarking and establishing engineering specifications, product portfolios. Value engineering in product design: Introduction, historical perspective, nature & measurement of value, importance of value, value analysis job plan, steps for solving & value analysis, value analysis tests		
Unit No: IV	**Product Lifecycle Management**	**10 Hours**
Concept of Product Life Cycle, Components / Elements of PLM, Emergence of PLM, Significance of PLM, Customer Involvement, Threads of PLM-computer aided design (CAD), Product data management (PDM), Comparison of PLM to Enterprises Resource planning (ERP). Integration of PLM & CAD, Introduction to PLM tools.		
Unit No: V	**Product Data Management**	**08 Hours**
Benefits and Terminology, CIM Data, PDM functions, definition and architectures of PDM systems, Engineering data, engineering workflow and PDM acquisition and implementation, Resolving Data Issues, product data interchange, collaborative product development, Internet and developments in client server computing, portal integration. Components of a typical PDM setup - hardware and document management – creation and viewing of documents - creating parts-version - control of parts and documents, configuration management for product structure, change management and associated activities.		

Reference Books

1. John W Gosnay and Christine M Mears, **Business Intelligence with Cold Fusion**, Prentice Hall India, New Delhi, 2000.
2. David S Linthicum, "**B2B Application Integration**", Addison Wesley, Boston, 2001.
3. Alexis Leon, **Enterprise Resource Planning**, Tata McGraw Hill, New Delhi, 2002.
4. David Ferry and Larry Whipple, **Building and Intelligent e-business**, Prima Publishing, EEE Edition, California, 2000.
5. S.Rosenthal, **Effective product design and development**, Irwin 1992.
6. **Product Design** by Otto and Wood, Pearson
7. David Bedworth, Mark Hederson and Phillip Wolfe, **Computer Integrated Design and Manufacturing**, McGraw Hill Inc., New York, 1991.
8. Kevin Otto and Kristin Wood, **Product Design – Techniques in Reverse Engineering and New Product Development**, Pearson Education, New Delhi, 2004.
9. Karl T Ulrich and Stephen D Eppinger, **Product Design and Development**, McGraw Hill, New York, 1994.
10. Grieves, Michael, **Product Lifecycle Management**, McGraw-Hill, 2006. ISBN 0071452303
11. AnttiSaaksvuori, AnselmiImmonen, **Product Life Cycle Management** - Springer, 1st Edition (Nov.5, 2003)
12. Stark, John, **Product Lifecycle Management**: Paradigm for 21st Century Product Realization, Springer-Verlag, 2004. ISBN 1852338105
13. Kari Ulrich and Steven D. Eppinger, **Product Design & Development**, McGraw Hill International 1999.
14. Burden Rodger, PDM: **Product Data Management**, Resource Pub, 2003. ISBN 0970035225
15. Silberschatz, Korth and Sudarshan, **Database System Concepts**, McGraw Hill, 2002, Database System Concepts, McGraw Hill, 2002

Learning Resources

4. Links to online SWAYAM/NPTEL Courses

M1. **https://nptel.ac.in/courses/112107217**
M2. **https://archive.nptel.ac.in/courses/112/107/112107217/**

Savitribai Phule Pune University Board: Mechanical Engineering ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)	
Course Code: PCC-553-CME	**Course Name: Simulation and Modelling**

Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	: 04	4	CCE	: 50
Practical	: --		ESE	: 50
Tutorial	: --		PR	: --

Prerequisite: Basics of Probability and Statistics, Fundamentals of Programming (preferably in C/Python/Java), Understanding of mathematical modeling and basic operations research.

Course Objectives:

1. To introduce the fundamental concepts of simulation and manual modeling approaches using discrete event simulation.
2. To explain the generation and testing of random numbers and variates, and their importance.
3. To guide students through the process of building reliable simulation models.
4. To enable students to model real-world manufacturing systems and evaluate system performance.
5. To introduce students to professional simulation packages and train them in practical model.

Course Outcomes:

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

1. Explain fundamental concepts of simulation and perform basic manual simulations.
2. Generate and test random numbers and variates for simulation applications.
3. Build simulation models with verified inputs and analyze stochastic outputs.
4. Model and evaluate performance in manufacturing systems with randomness.
5. Implement and analyze simulation models using software tools.

Course Contents

Unit No: I	**Introduction to Simulation and Modelling**	**10 Hours**

Definition, history, nature and limitations of simulation. System components and environment. Types of simulation: discrete and continuous. Modelling approaches. Manual simulation examples: event scheduling, single-channel queue, two-server queue, inventory problem.

Unit No: II	**Automated Manufacturing Systems**	**10 Hours**

Random number generation methods: mid-square, mid-product, constant multiplier, congruential methods, feedback shift register. Tests: frequency, Kolmogorov-Smirnov, chi-square, independence tests. Random variate generation: inverse transform, acceptance-rejection. Distributions: exponential, uniform, Weibull, normal, Poisson, gamma, geometric.

Unit No: III	**Pneumatic and hydraulic components and circuits**	**10 Hours**

Data collection, identifying distributions, parameter estimation, goodness-of-fit tests, input models without data. Model verification and validation. Variance reduction, antithetic variables. Output analysis: performance metrics, terminating simulations.

Unit No: IV	**Manufacturing Plant Automation**	**10 Hours**

Modelling objectives and performance measures. System randomness: sources and handling. Machine downtime. Case study of manufacturing system simulation.

Unit No: V	**Manufacturing Enterprise System**	**08 Hours**

Introduction to simulation software packages. Model building and experimentation using tools. Practical exercises and case studies.

Reference Books
1. Jerry Banks, John S, Carson II, Barry L Nelson and David M Nicol, **"Discrete Event System Simulation",** Prentice Hall Inc., 2006. 2. Law A M, **"Simulation Modeling and Analysis**", Tata McGraw Hill Companies Inc, 2008. 3. Gordon G, **"Systems Simulation**", Prentice Hall Ltd., 2006. 4. Narsingh Deo, **"System Simulation with Digital Computer**", Prentice Hall of India, 2007. 5. Francis Neelamkovil, **"Computer Simulation and Modeling**", John Wiley and Sons, 1987. 6. Ruth M Davis and Robert M O'Keefe, "**Simulation Modeling with Pascal",** Prentice Hall Inc., 1989.

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PCC-554-CME	**Course Name: Lab Practice – III**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : --		CCE : --
Practical : 4	4	ESE : --
Tutorial : --		PR : 25 TW : 25

Prerequisite:

- Basic understanding of core mechanical engineering subjects such as Machine Design, Heat Transfer, and Theory of Machines
- Familiarity with CAD software and simulation tools
- Ability to read engineering drawings and technical specifications

Course Objectives:

1. To introduce students to the application of finite element analysis (FEA) in manufacturing processes such as heating/cooling, bending, and forming.
2. To develop the ability to simulate machining operations such as turning and milling using modern tool path simulation software.
3. To train students in interpreting simulation results for improving process efficiency and quality.
4. To enhance problem-solving skills by engaging students in the optimization of manufacturing process parameters.
5. To bridge the gap between theoretical knowledge and industrial application through hands-on assignments using advanced simulation tools.

Course Outcomes:

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

1. Simulate and analyze thermal processes (cooling/heating) using finite element methods and interpret the temperature profiles.
2. Perform finite element simulations for bending and drawing/forming operations, identifying stress-strain behavior and potential defects.
3. Generate and analyze tool paths for turning and milling operations, ensuring efficiency and precision in machining.
4. Apply optimization techniques to improve process performance by adjusting key parameters like speed, feed, or temperature.
5. Demonstrate competency in using simulation software to evaluate, modify, and document manufacturing processes for real-world engineering problems.

List of Experiments

Perform **all** experiments from following list:

1. Assignment on Finite Element Simulation of Cooling/Heating Process.
2. Assignment on Finite Element Simulation of Bending Process.
2. Assignment of Finite Element Simulation of Drawing/Forming.
4. Assignment on Tool Path Simulation of Turning/Milling.
5. Assignment on Process Optimization.

Guidelines for Instructor's Manual

Course Planning:

Guidelines for Students Lab Manual
Each lab report should include: Title of experiment, Aim, Apparatus/tools used, Theory/concept, Procedure, Observations/data, Calculations
Guidelines for Lab assessment
Guidelines for Lab conduction
• Assignment on real life problems of manufacturing systems and manufacturing processes to be simulated using simulation software's as ARENA, FORGE, FASTFORM ADVANCED, PAMSTAMP, SIMUFACT FORMING etc. • Assignments on optimization using any process/product optimization software.

Learning Resources
1. Test Books
1. Larry J. Segerlind "Applied Finite Element Analysis", Wiley **2.** J.P. Holman "Heat Transfer", McGraw Hill **3.** William F. Hosford & Robert M. Caddell "Metal Forming: Mechanics and Metallurgy" **4.** Serope Kalpakjian & Steven Schmid "Manufacturing Processes for Engineering Materials", Pearson Education **5.** S.S. Rao "Engineering Optimization: Theory and Practice", Wiley
2. Reference Books
1. S.S. Rao "Finite Element Method in Engineering", Elsevier **2.** Kim and Sankar "Introduction to Finite Element Analysis and Design", Wiley **3.** P.N. Rao "CAD/CAM: Principles and Applications", McGraw Hill **4.** Suhas V. Patankar "Numerical Heat Transfer and Fluid Flow", CRC Pres
3. e-Books
1. Fundamentals of Modern Manufacturing by Mikell P. Groover – Wiley Online Library **2.** Heat and Mass Transfer by Yunus A. Çengel – McGraw Hill eBook Store **3.** An Introduction to the Finite Element Method by J.N. Reddy – Pearson India eBooks
4. Links to online SWAYAM/NPTEL Courses

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PEC-571A-CME	**Course Name: Energy Audit and Management**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03	3	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite: Students should have a basic understanding of manufacturing processes, CAD/CAM fundamentals, and principles of energy systems. Knowledge of machine tools, automation, and basic energy concepts in grasping energy management and optimization in digital manufacturing.

Course Objectives:
1. To understand the basics of energy systems and their interaction with CAD/CAM environments.
2. To apply audit techniques for energy assessment in CAD/CAM-based manufacturing.
3. To optimize energy use in design and production using CAD tools and simulation.
4. To evaluate and reduce energy consumption in CAM-driven machining systems.
5. To promote sustainability and smart energy management in CAD/CAM-based systems.

Course Outcomes:
Upon successful completion of this course, the students will be able to:
1. Recognize energy-consuming elements in CAD/CAM systems and explore efficiency improvements.
2. Perform energy audits using CAD/CAM-linked data and instrumentation.
3. Utilize CAD-based simulations to assess and enhance energy performance.
4. Recommend CAM-based process modifications to minimize energy use.
5. Integrate sustainable design principles into CAD/CAM workflows and smart manufacturing.

Course Contents

Unit No: I	**Energy Systems and CAD/CAM Relevance**	**08 Hours**

Basic energy concepts, types of energy in manufacturing. Energy usage in CAD/CAM environments – CNC, robotics, material handling. Energy-efficient design concepts through CAD modelling and simulation.

Unit No: II	Energy Audit Techniques in Manufacturing Systems	**06 Hours**

Types and procedures of energy audits in industrial setups. Energy auditing tools and software for CNC machines, PLC-based systems, and automated processes. Integration of CAD/CAM data with energy monitoring systems.

Unit No: III	Energy Management and Optimization Using CAD Tools	**08 Hours**

Energy management principles tailored to digital manufacturing. Role of simulation (e.g., CFD, FEA) in thermal/electrical energy analysis. Case studies: optimizing tool paths, layout design, and production cycles for energy efficiency.

Unit No: IV	Energy-Efficient Machine Tools and CAM Systems	**06 Hours**

Energy consumption metrics for CNC machines, robotics, and CAM operations. Design modifications for reducing idle time, tool changes, and redundant operations. CAM software features for energy-efficient machining and cycle time reduction.

Unit No: V	Sustainable Manufacturing and Smart Energy Systems	**08 Hours**
Sustainable product design using CAD tools (eco-design, material selection). Smart factory concepts, Green manufacturing case studies and role of CAD/CAM in implementing ECBC/LEED standards.		

Reference Books
1. **Bureau of Energy Efficiency (BEE)** – *Energy Manager Guide Books (Vol I-IV)*
2. Yusuf Altintas, **Manufacturing Automation: Metal Cutting Mechanics, Machine Tool Vibrations, and CNC Design,** Cambridge University Press.
3. M. F. Spotts, T. E. Shoup, **Design of Machine Elements (for energy in design),** Prentice-Hall.
4. T. R. Kurfess, **Robotics and Automation Handbook,** CRC press, Boca Raton London New York Washington, D.C.
5. S. K. Choudhury, **Energy-Efficient Manufacturing Systems**

Learning Resources
4. Links to online SWAYAM/NPTEL Courses
M1. https://archive.nptel.ac.in/courses/112/106/112106064/ M2. https://archive.nptel.ac.in/courses/110/104/110104119/ M3. https://archive.nptel.ac.in/courses/112/104/112104225/

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PEC-571B-CME	**Course Name: Project and Financial Management**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03	3	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite: Students should have a basic understanding of engineering economics and fundamental concepts of CAD/CAM systems. Familiarity with mathematical tools for analysis and general management principles.

Course Objectives:

1. To understand how to identify and justify investments for engineering projects.
2. To provide financial tools to assess the viability of projects.
3. To understand different financing mechanisms and energy contracting models.
4. To introduce planning, design, and contracting phases of a project.
5. To impart knowledge on project execution, budgeting, and performance monitoring.

Course Outcomes:

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

1. Identify investment needs and assess them using relevant appraisal criteria.
2. Apply financial techniques to evaluate project viability and risks.
3. Choose appropriate financing options and evaluate the function of ESCOs in energy projects.
4. Develop a structured approach to project design, scope definition, and contract formulation.
5. Create implementation and monitoring plans with budgeting, procurement, and verification elements.

Course Contents

Unit No: I	**Investment Need and Appraisal**	**07 Hours**

Introduction to investment in engineering and industrial systems. Identification of investment needs and strategic alignment. Investment appraisal methods (qualitative and quantitative methods) and selection criteria (need-based, return-based). Factors influencing investment decisions.

Unit No: II	**Financial Analysis Techniques**	**08 Hours**

Simple Payback Period and Return on Investment (ROI). Net Present Value (NPV) and Internal Rate of Return (IRR). Cash flow estimation and discounted cash flow techniques. Introduction to risk analysis and sensitivity analysis.

Unit No: III	**Financing and Energy Contracting Models**	**07 Hours**

Sources of project financing and financial structuring. Overview of Energy Performance Contracting (EPC). Role and functioning of Energy Service Companies (ESCOs). Contract models and financial incentives in energy projects.

Unit No: IV	**Project Planning and Design**	**07 Hours**

Definition and scope of projects. Feasibility studies and technical design integration. Work Breakdown Structure (WBS) and planning tools. Types of contracts and basic legal considerations.

Unit No: V	Implementation and Monitoring	07 Hours
Development of implementation plans and budgeting. Procurement procedures and construction scheduling. Monitoring tools for cost and progress tracking. Measurement and Verification (M&V) techniques.		

Reference Books
1. **Bureau of Energy Efficiency (BEE)** – *Energy Manager Guide Books (Vol I-IV)*
2. Prasanna Chandra, **Projects: Planning, Analysis, Selection, Financing, Implementation, and Review**, Tata McGraw-Hill.
3. Harold Kerzner, **Project Management: A Systems Approach to Planning, Scheduling, and Controlling,** Wiley.
4. P. K. Sinha, **Financial Management**, Excel Books.
5. Bhavesh M. Patel, **Project Management: Strategic Financial Planning, Evaluation and Contro***l*, Vikas Publishing.

Learning Resources	
4. Links to online SWAYAM/NPTEL Courses	
M1.	https://archive.nptel.ac.in/courses/110/105/110105166/
M2.	https://archive.nptel.ac.in/courses/110/107/110107073/
M3.	https://archive.nptel.ac.in/courses/109/101/109101171/
M4.	https://archive.nptel.ac.in/courses/105/106/105106149/

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PEC-571C-CME | **Course Name: Technology Transfer**

Teaching Scheme		Credits	Examination Scheme	
Theory	: 03	3	CCE	: 50
Practical	: --		ESE	: 50
Tutorial	: --		PR	: --

Prerequisite: Students should have a basic understanding of product development, innovation management, and industrial engineering concepts. Familiarity with research methodologies and technology management principles is recommended.

Course Objectives:

1. To understand the basic concepts and sources of technology transfer.
2. To analyze success and failure factors in technology transfer.
3. To differentiate between invention and innovation and explain R&D classifications.
4. To describe the NPD process and commercialization challenges.
5. To understand roles of stakeholders in technology transfer.

Course Outcomes:

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

1. Describe technology transfer and identify its sources and models.
2. Evaluate factors influencing the effectiveness of technology transfer.
3. Illustrate the significance of R&D and innovation in technology transfer.
4. Outline the NPD stages and identify commercialization barriers.
5. Explain collaboration and policy frameworks supporting technology transfer.

Course Contents

Unit No: I	Introduction to Technology Transfer	07 Hours

Definition, objectives, and importance of technology transfer. Sources of technology transfer including internal and external channels. Models of technology transfer with emphasis on public and private enterprise interactions.

Unit No: II	Factors Affecting Technology Transfer	07 Hours

Critical success and failure factors in technology transfer. Barriers and enablers in technology adoption. Case studies highlighting practical challenges in transferring technology.

Unit No: III	Invention, Innovation, and Research & Development (R&D)	07 Hours

Concepts of invention and innovation. Definition and classifications of R&D activities. Role of R&D in technology advancement and product development.

Unit No: IV	New Product Development (NPD)	07 Hours

Stages of new product development. Strategies for NPD. Challenges and barriers in commercializing research outcomes. Technology readiness and market introduction.

Unit No: V	Public and Private Sector Roles in Technology Transfer	08 Hours
Role of government, research institutions, and private companies in technology dissemination. Collaboration models, licensing, and intellectual property considerations. Policies and incentives for technology transfer.		

Reference Books

1. Tarek Khalil, **Management of Technology: The Key to Competitiveness and Wealth Creation**, McGraw-Hill.
2. V.K. Narayanan, **Managing Technology and Innovation for Competitive Advantage**, Pearson.
3. Gerard H. Gaynor, **Hand Book of Technology Management,** Mc Graw Hill.
4. Donald F. Kuratko, **Entrepreneurship: Theory, Process, Practice**, Cengage Learning.

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PEC-571D-CME	**Course Name: Intellectual Property Rights**

Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	: 03	3	CCE	: 50
Practical	: --		ESE	: 50
Tutorial	: --		PR	: --

Prerequisite: Students should possess basic knowledge of design principles, product development cycles, and general awareness of legal and ethical aspects in research.

Course Objectives:

1. To understand the scope and significance of IPR and patentability criteria.
2. To explain patent application and granting procedures.
3. To describe different forms of IP and their protections.
4. To analyze IPR management and enforcement strategies.
5. To apply IPR knowledge through case study analysis.

Course Outcomes:

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

1. Identify patentable inventions and relevant statutory exceptions.
2. Outline the process and rights associated with patent applications.
3. Differentiate among trademarks, copyrights, and trade secrets.
4. Explain methods for IP commercialization and protection.
5. Prepare and present IPR-related case reports effectively.

Course Contents

Unit No: I	**Fundamentals of Intellectual Property Rights**	**07 Hours**

Definition, scope, and classification of intellectual property. Criteria for patentability and non-patentable inventions. Statutory exceptions and identification of eligible applicants for patents.

Unit No: II	**Patent Filing and Legal Provisions**	**07 Hours**

Detailed procedures for patent application, documentation, and filing. Examination process, opposition proceedings, and patent grant protocols. Patent holder rights, term of protection, and legal implications.

Unit No: III	**Forms of Intellectual Property**	**07 Hours**

Characteristics and legal basis for trademarks, copyrights, and design rights. Trade secrets and confidential information protection. Comparison of different IP types and their relevance in industrial applications.

Unit No: IV	**Management, Licensing, and Enforcement**	**07 Hours**

IPR strategy, licensing, technology transfer, and commercialization. Infringement issues, legal remedies, and enforcement mechanisms. Role of national and international IP organizations.

Unit No: V	**Practical Application and Case Studies**	**08 Hours**

Preparation of case reports involving IP filing and protection in engineering contexts. Review and discussion of real-life IP disputes and innovations in CAD/CAM. Ethical, legal, and commercial considerations in handling intellectual property.

Reference Books

1. P. Narayanan, **Patent Law**, Eastern Law House.
2. Satyawrat Ponkshe, **The Management of Intellectual Propert**y, Ponkshe & Bhate Publications, Pune.
3. W.R. Cornish, **Intellectual Property: Patents, Copyright, Trademarks & Allied Rights,** Sweet & Maxwell.
4. Prabuddha Ganguli, **Intellectual Property Rights: Unleashing the Knowledge Economy**, McGraw-Hill Education.
5. B.L. Wadehra, **Law Relating to Intellectual Property**, Universal Law Publishing.

Learning Resources

1. https://www.nitap.ac.in/storage/pdf/f63d0ea9127821f83a5a4ad9f1531be8-10-04-11of%20IPR.pdf
2. https://www.nitrkl.ac.in/docs/AcademicRegulation/08032017102915702.pdf

4. Links to online SWAYAM/NPTEL Courses

M1. https://archive.nptel.ac.in/courses/110/105/110105139/
M2. https://onlinecourses.swayam2.ac.in/aic21_ge20/preview

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PEC-572A-CME	**Course Name: Advanced Materials and Alloys**

Teaching Scheme		**Credits**	**Examination Scheme**	
Theory	: 03	3	CCE	: 50
Practical	: --		ESE	: 50
Tutorial	: --		PR	:

Prerequisite: Students should have a foundational understanding of materials science and engineering, including atomic structure, crystallography, phase diagrams, and diffusion mechanisms. A background in metallurgy particularly knowledge of metals and alloys, strengthening methods, and heat treatment is essential. Familiarity with basic thermodynamics, phase transformations, and mechanical behavior of materials (such as stress-strain relationships and failure modes) is also required.

Course Objectives:

1. To provide in-depth knowledge of advanced materials, their structure, properties, and applications.
2. To study the development, processing, and characterization of modern alloys and composite materials.
3. To explore the relationship between microstructure and mechanical properties in engineered materials.
4. To understand the applications of nanomaterials, smart materials, and functionally graded materials.
5. To enhance research-oriented understanding and application of materials in emerging technologies and industries.

Course Outcomes:

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

1. Explain the classification, structure, and properties of advanced engineering materials.
2. Analyze the composition and performance of high-performance alloys used in aerospace, automotive, and biomedical applications.
3. Select and justify appropriate materials for specialized applications based on performance requirements.
4. Apply principles of materials science to understand smart and nanomaterials behavior.
5. Interpret and evaluate experimental and computational data related to materials characterization and processing.

Course Contents

Unit No: I	**Introduction to Advanced Materials**	**08 Hours**

Classification of engineering materials: metals, ceramics, polymers, composites, and advanced materials. Advanced structural materials: high-strength steels, superalloys, titanium alloys, intermetallics. Advanced functional materials: piezoelectric, magnetostrictive, thermoelectric, optoelectronic. Physical, chemical, mechanical, and thermal properties. Role of crystal structure, grain size, and phase in determining material behaviour.

Unit No: II	**Advanced Alloys and Their Processing**	**06 Hours**

High-performance alloys: Nickel-based, Cobalt-based, Titanium-based, Aluminum-lithium alloys. Metallurgy of superalloys and their applications in high-temperature environments. Bulk metallic glasses, shape memory alloys (SMAs), and quasicrystals. Processing techniques: Vacuum induction melting, powder metallurgy, rapid solidification. Heat treatment and thermomechanical processing of advanced alloys.

Unit No: III	Composite and Hybrid Materials	08 Hours
Types: Particle-reinforced, fiber-reinforced, structural composites. Metal matrix composites (MMCs), polymer matrix composites (PMCs), ceramic matrix composites (CMCs). Interface bonding, load transfer mechanism, failure modes. Fabrication methods: Liquid infiltration, diffusion bonding, spray deposition, hot pressing. Applications in aerospace, automotive, defense, and sports equipment.		
Unit No: IV	**Nanomaterials and Smart Materials**	**06 Hours**
Nanomaterials: Synthesis (chemical vapor deposition, sol-gel, mechanical milling), properties, and applications. Smart materials: Piezoelectric, electrostrictive, magnetorheological, thermochromic, shape memory materials. Nanocomposites and their structural advantages. Surface engineering using nanocoatings and thin films. Applications in sensors, actuators, MEMS/NEMS, and biomedical devices.		
Unit No: V	**Material Characterization and Selection**	**08 Hours**
Characterization techniques: SEM, TEM, XRD, DTA/TGA, FTIR, AFM, nanoindentation. Phase diagrams and thermodynamic stability of phases. Criteria for material selection: performance indices, cost analysis, life-cycle assessment. Case studies on material failure and reliability. Role of computational materials science (CALPHAD, ICME, DFT) in alloy design and prediction.		

Learning Resources

Test Books

1. "Engineering Materials: An Introduction to Properties, Applications and Design" by Michael F. Ashby and David R.H. Jones
2. "Mechanical Metallurgy" by George E. Dieter
3. "Mechanics of Composite Materials" by Robert M. Jones
4. "Composite Materials: Science and Engineering" by Krishan K. Chawla
5. "Introduction to Polymer Science and Chemistry: A Problem-Solving Approach" by Robert W. Lyons and Paul A. Leary
6. "Engineering Plastics: An Introduction to Engineering Plastics" by Charles A. Harper
7. "Smart Materials and Structures" by M. A. Male and M. H. A. Hargreaves
8. "Introduction to Nano-materials and Nanotechnology" by Joseph J. D. and Thomas J. Over
9. "Heat Treatment, Selection, and Application of Tool Steels" by William E. Bryson
10. "Principles of Heat Treatment" by J. A. Charles and J. W. Burch
11. "Mechanics of Materials" by Ferdinand P. Beer, E. Russell Johnston Jr., John T. De Wolf, and David F. Mazurek

2. Reference Books

1. Fundamentals of Materials Science and Engineering, William D. Callister, Jr., John Wiley & Sons,
2. Mechanical Metallurgy, George E. Dieter, McGraw Hill Book Company, 1988
3. Theory of Plasticity, J. Chakrabarty, Elsevier, 2006
4. Foundations of Theory of Plasticity, L. M. Kachanov, Dover Publications, 2004
5. Theory of Plasticity and Metal Forming Processes, Sadhu Singh, Khanna Publishers
6. Mechanical Behavior of Materials, W.F.Hosford, Cambridge University Press, 2005
7. Plasticity for Structural Engineers, W.F. Chen, Da-Jian Han, Springer

3. Links to online SWAYAM/NPTEL Courses

M1. "Materials Science and Engineering" by IIT Madras

M2. "Mechanical Behavior of Materials" by IIT Madras

M3. "Composite Materials" by IIT Kharagpur
M4. "Introduction to Polymer Science" by IIT Madras
M5. "Nanomaterials" by IIT Madras
M6. "Heat Treatment of Metals" by IIT Madras
M7. "Mechanics of Materials" by IIT Kharagpur
M8. "Theory of Elasticity and Plasticity" by IIT Kharagpur
M9. "Experimental Methods in Mechanics" by IIT Kharagpur

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PEC-572B-CME		**Course Name: Composites and Ceramics**
Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03	3	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite: Students should have a fundamental understanding of materials science and engineering, particularly the structure-property relationships of metals, polymers, and ceramics. Prior knowledge of basic concepts such as crystallography, mechanical behavior (stress-strain, hardness, toughness), and phase diagrams is essential. Familiarity with manufacturing processes, thermodynamics of materials, and introductory-level composite materials will help in comprehending advanced topics. Basic laboratory skills and experience with material characterization techniques such as microscopy and hardness testing are also recommended.

Course Objectives:

1. To impart fundamental and advanced knowledge of composite materials and ceramic materials.
2. To explore various reinforcement types, matrix materials, and processing techniques for composites.
3. To understand the structure-property relationships and toughening mechanisms in ceramics.
4. To develop knowledge of applications, design considerations, and failure mechanisms of both composites and ceramics.
5. To equip students with characterization techniques and material selection methods relevant to composites and ceramics.

Course Outcomes:

1. Upon successful completion of this course, the students will be able to:
2. Explain the types, constituents, and classifications of composite and ceramic materials.
3. Analyze the mechanical behavior and failure modes of fiber-, particle-, and matrix-reinforced composites.
4. Understand the structure, processing, and properties of traditional and advanced ceramics.
5. Evaluate the design, manufacturing, and application criteria for composite and ceramic components.
6. Apply characterization techniques and interpret material data for advanced material selection and design.

Course Contents

Unit No: I	**Fundamentals of Composite Materials**	**08 Hours**

Definition, classification, and advantages of composites. Constituents: matrix materials (polymer, metal, ceramic), reinforcements (fibers, whiskers, particles). Types of composites: PMC, MMC, CMC, hybrid composites. Properties and roles of matrix and reinforcement. Rule of mixtures and micromechanics of composites.

Unit No: II	**Processing and Manufacturing of Composites**	**06 Hours**

Polymer Matrix Composites (PMC): hand lay-up, resin transfer molding, autoclave curing. Metal Matrix Composites (MMC): stir casting, powder metallurgy, diffusion bonding. Ceramic Matrix Composites (CMC): chemical vapor infiltration, sol-gel processing. Interface bonding and surface treatment of fibers. Challenges in processing: fiber alignment, porosity, residual stresses.

Unit No: III	**Mechanical Behavior and Failure Mechanisms**	**08 Hours**

Stress-strain behavior of composites. Load transfer mechanism and failure criteria (maximum stress, strain, Tsai-Wu). Interfacial debonding, delamination, matrix cracking, fiber pull-out. Fatigue, creep, and impact behavior in composites. Testing methods: tensile, flexural, interlaminar shear, impact tests.

Unit No: IV	**Ceramic Materials – Structure, Processing, and Properties**	**06 Hours**
Classification: traditional vs advanced ceramics. Crystal structures and bonding (ionic/covalent). Processing of ceramics: powder preparation, shaping (dry pressing, slip casting, tape casting), sintering. Mechanical properties: hardness, brittleness, fracture toughness, wear resistance. Thermal and electrical properties; toughening mechanisms in ceramics.		
Unit No: V	**Applications, Characterization, and Material Selection**	**08 Hours**
Applications of composites in aerospace, automotive, defense, biomedical, and sports. Applications of ceramics in electronics, cutting tools, bio-implants, and thermal barriers. Characterization techniques: SEM, TEM, XRD, DMA, TGA, dilatometry. Nondestructive testing of composites and ceramics. Case studies in material selection and failure analysis.		

Learning Resources

1. Test Books

1. Chawla K.K., Composite materials Science and Engineering, Springer – Springer New York2016
2. Daniel Gay- Composite Materials- Design and Applications, CRC Press, 2014
3. Autar Kaw- Mechanics of Composite Materials, Taylor and Francis, Second Edition- 2006
4. Robert M Jones-Mechanics of Composite Material, CRC Press, 2018
5. Madhujit Mukhopadhyay - Mechanics of Composite Materials and Structure, University Press, 2004
6. S.C. Sharma -Composite Materials, Narosa Publishing House—2000

2. Reference Books

1. A Bent Strong- Fundamentals of Composites Manufacturing-Materials, Methods and Applications, Society of Manufacturing Engineers, 2008
2. Clyne T.W. and Withers P.J-Introduction to Metal Matrix Composites, Cambridge University Press, 1995
3. Agarwal B. D. and Broutmen L. J-Analysis and performance of Fiber Composites, Wiley Publicaions-Fourth Edition, 2017
4. M. W. Hyer, Scott R. White- Stress Analysis of Fiber-reinforced Composite Materials, DEStech Publications, Inc., 2009
5. Carl T. Herakovich- Mechanics of Fibrous Composites, Wiley Publicaions, 1998
6. Erich Fitzer, Lalit M. Manocha - Carbon Reinforcements and Carbon /carbon Composites, Springer-Verlag, 1998
7. Murray Schwartz, Mel M. Schwartz- Composite Materials Handbook, McGraw-Hill, 1992
8. Composite Materials Handbook, SAE International, 2017

3. Links to online SWAYAM/NPTEL Courses

1. Introduction of Composite - https://nptel.ac.in/courses/112/104/112104229/
2. Advanced Composite - https://nptel.ac.in/courses/112/104/112104249/
3. Polymer Process - https://nptel.ac.in/courses/113/105/113105077/
4. Manufacturing of composite - https://nptel.ac.in/courses/112/104/112104221/
5. Processing of Polymer composite - https://nptel.ac.in/courses/112/107/112107221/
6. Composite materials - https://nptel.ac.in/courses/101/106/101106038/
7. Mechanics of laminated of composite - https://nptel.ac.in/courses/112/104/112104161/
8. Composite Materials and Structure - https://nptel.ac.in/courses/101/104/101104010

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PEC-572C-CME	**Course Name: Robotics and Automation**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03	3	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite: Students should have a foundational understanding of basic knowledge of engineering mechanics and control systems. Familiarity with electrical drives and manufacturing processes will be beneficial.

Course Objectives:

1. To understand the fundamental concepts of robotics and automation systems.
2. To analyze robotic kinematics, dynamics, and control strategies.
3. To explore actuators, sensors, and end-effectors used in robotic systems.
4. To study the integration of automation in manufacturing and industrial systems.
5. To gain insights into robotic programming and modern trends in automation.

Course Outcomes:

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

1. Describe the architecture and classifications of robots and automation systems.
2. Apply kinematic and dynamic principles to robotic mechanisms.
3. Select appropriate actuators and sensors for specific robotic applications.
4. Design and analyze automation layouts for manufacturing processes.
5. Develop simple robotic programs and demonstrate knowledge of Industry 4.0 applications.

Course Contents

Unit No: I	**Introduction to Robotics and Automation**	**08 Hours**

History and development of robotics and automation. Definitions and types of robots (articulated, SCARA, Cartesian, cylindrical). Applications in manufacturing, medical, aerospace, and service sectors. Basic components of a robot: manipulator, controller, sensors, and actuators. Levels of automation and types (fixed, programmable, flexible)

Unit No: II	**Kinematics and Dynamics of Robots**	**06 Hours**

Robot configurations and workspaces. Forward and inverse kinematics of serial manipulators. Denavit-Hartenberg (D-H) parameters and transformation matrices. Differential motion and Jacobians. Dynamics using Euler-Lagrange and Newton-Euler formulations

Unit No: III	**Robot Actuators, Sensors, and End-Effectors**	**08 Hours**

Types of actuators: electric, hydraulic, and pneumatic. Types of sensors: position, velocity, force/torque, proximity, and vision sensors. Feedback and closed-loop control in robots. Types and selection of end-effectors: grippers, tools, and welding torches. Sensor integration and interfacing basics

Unit No: IV	**Industrial Automation and Control**	**06 Hours**

Introduction to PLCs, SCADA, and HMI systems. Ladder logic basics and example programs. Pneumatic and hydraulic automation systems. Automated Material Handling: AGVs, conveyors, pick-and-place systems. Introduction to CNC automation and integration with robotics.

Unit No: V	**Robotic Programming and Modern Automation Trends**	**08 Hours**

Introduction to robotic languages (e.g., VAL, RAPID, KRL). Offline and online programming methods. Path planning and trajectory generation. Human-robot collaboration (HRC). Introduction to Industry 4.0: IoT, cyber-physical systems, and smart factories

Learning Resources
Test Books
1. Automation, Production systems and CIM, M.P. Groover /Pearson Edu. 2. Industrial Robotics - Mikell P. Groover and Mitchell Weiss, Roger N. Nagel, Nicholas, G.Odrey - McGraw Hill.
2. Reference Books
1. Robotics and control - RK Mittal and I J nagrath, TataMcGraw Hill. 2. An Introduction to Robot Technology, P. Coiffet and M. Chaironze, Kogam Page Ltd., London. 3. Robotic Engineering - integrated approach by Richard d Klafter-London: Prentice-Hall. 4. Robotics, Fundamental Concepts and analysis –Ashitave Ghosal, Oxford Press 5. Introduction to Robotics - John J. Craig, PearsonEdu.
3. Links to online SWAYAM/NPTEL Courses
1. http://nptel.iitm.ac.in/courses.php?branch=Mechanical 2. http://academicearth.org/courses/introduction-to-robotics 3. http://nptel.iitm.ac.in/video.php?courseld=1052 **4.** http://www.nptel.iitm.ac.in/and iitb.ac.in

Savitribai Phule Pune University
Board: Mechanical Engineering
ME (Computer Aided Design, Manufacture & Engineering) (2025 Pattern)

Course Code: PEC-572D-CME	**Course Name: Computational Fluid Dynamics**

Teaching Scheme	**Credits**	**Examination Scheme**
Theory : 03	3	CCE : 50
Practical : --		ESE : 50
Tutorial : --		PR : --

Prerequisite: Fluid Mechanics, Heat transfer, Numerical methods, Programming Languages.

Course Objectives:

1. To introduce the fundamentals of CFD and develop understanding of the governing equations in fluid flow and heat transfer.
2. To apply finite volume method (FVM) for solving 2D steady and unsteady heat conduction problems.
3. To formulate and solve advection-dominated heat transfer problems using FVM and various discretization schemes.
4. To solve convection-diffusion equations for heat transfer problems using FVM with attention to stability and Peclet number.
5. To simulate incompressible viscous flows using Navier–Stokes equations and SIMPLE algorithm.

Course Outcomes:

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

1. Interpret the physical significance of mass, momentum, and energy equations along with appropriate boundary conditions.
2. Solve conduction problems using explicit and implicit schemes with various boundary conditions and assess stability.
3. Analyze and implement different numerical schemes like upwind, central difference, and QUICK for advection solutions.
4. Evaluate transient and steady convection-diffusion behavior using appropriate discretization and numerical schemes.
5. Implement numerical methods to solve cavity flow problems and understand basics of external flow simulation.

Course Contents

Unit No: I	**Introduction to CFD**	**07 Hours**

Introduction to Computational Fluid Dynamics, Derivation and physical interpretation of governing equations (conservation of mass, momentum and energy) in differential form, Concept of substantial derivative, divergence and curl of velocity, Mathematical behavior of Governing Equations and boundary conditions.

Unit No: II	**Solution to Conduction Equation**	**07 Hours**

Introduction to FEA, FDM and FVM, Solution of two dimensional steady and unsteady heat conduction equation using finite volume method (Implicit and Explicit) with Dirichlet, Neumann, Robbin boundary conditions, Stability Criteria.

Unit No: III	**Solution to Advection Equation**	**07 Hours**

Solution of two dimensional steady and unsteady heat advection equation using finite volume method (Implicit and Explicit) with Dirichlet BC, Stability Criteria, Introduction to first order upwind, CD, second order upwind and QUICK convection schemes.

Unit No: IV	Solution to Convection-Diffusion Equation	07 Hours
Solution of two dimensional steady and unsteady heat convection-diffusion equation for slug flow using finite volume method (Implicit and Explicit), Stability Criteria, 1-D transient convectiondiffusion system, Peclet Number		

Unit No: V	Solution to Navier – Stokes Equation	08 Hours
Solution of Navier-Stoke‘s equation for incompressible flow using SIMPLE algorithms for lid driven cavity flow problem, Introduction to external flow simulation		

Reference Books

1. H. Tennekes and J. L. Lumley, **A First Course in Turbulence**, MIT Press.
2. David C. Wilcox, **Turbulence Modeling for CFD**, DCW Industries
3. 1. John D Anderson: **Computational Fluid Dynamics- The Basics with Applications**, McGrawHill
4. Atul Sharma, **Introduction to Computational Fluid Dynamics: Development, Application and Analysis**, Wiley
5. Suhas V. Patankar, **Numerical Heat Transfer and Fluid Flow**, Hemisphere Publishing Corporation
6. A. W. Date, **Introduction to Computational Fluid Dynamics**, Cambridge Univ. Press, USA.
7. H. Versteeg, and W.Malalasekara, **An Introduction to Computational Fluid Dynamics: The Finite Volume Method**, Pearson.
8. T. J. Chung, **Computational Fluid Dynamics**, Cambridge University Press.
9. J. Tu, G.-H. Yeoh and C. Liu: **Computational Fluid Dynamics: A practical approach**, Elsevier.
10. H. Schlichting and K. Gersten, **Boundary-Layer Theory**, Springer.

Learning Resources

3. Links to online SWAYAM/NPTEL Courses

M1. https://archive.nptel.ac.in/courses/112/107/112107079/
M2. https://archive.nptel.ac.in/courses/112/104/112104030/
M3. https://archive.nptel.ac.in/courses/103/106/103106119/
M4. https://archive.nptel.ac.in/courses/112/106/112106186/
M5. https://archive.nptel.ac.in/courses/103/106/103106119/