MK UNIVERSITY

PATAN, GUJARAT

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MK University, Patan
Faculty of Engineering Technology,
Department of Mechanical Engineering

M. TECH (MECHANICAL ENGINEERING) SEM-I										
SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/WEEK	PRACTICAL (HRS.)/WEEK	CREDITS	EXAMINATION		TOTAL MARKS
							INTERNAL	EXTERNAL	
1	MAJOR	MTME101	ADVANCED MATHEMATICS FOR ENGINEERS	4	0	4	40	60	100
2	MAJOR	MTME102	ADVANCED MECHANICS OF SOLIDS	4	2	6	90	60	150
3	MAJOR	MTME103	RESEARCH METHDOLOGY & TECHNICAL COMMUNICATION	4	0	4	40	60	100
4	MINOR	MTME104	PRODUCT DESIGN & DEVELOPMENT	4	2	6	90	60	150
5	SEC	MTME105	ENTERPRENURSHIP DEVELOPMENT	4	0	4	40	60	100
TOTAL				20	4	24	300	300	600

M. TECH (MECHANICAL ENGINEERING) SEM-II									
SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/WEEK	PRACTICAL (HRS.)/WEEK	CREDITS	EXAMINATION		TOTAL MARKS
							INTERNAL	EXTERNAL	
1	MAJOR	MTME201	ADVANCED DYNAMICS & VIBRATIONS	4	0	4	40	60	100
2	MAJOR	MTME202	REFERIGERATION & CRYOGENICS	4	2	6	90	60	150
3	MAJOR	MTME203	COMBUSTION ENGINEERING	4	2	6	90	60	150
4	MINOR	MTME204	ARTIFICIAL INTELLIGENCE & MACHINE LEARNING	4	2	6	90	60	150
5	VAC	MTME205	BUSINESS COMMUNICATION-I	2	0	2	0	50	50
TOTAL				18	6	24	310	290	600

M. TECH (MECHANICAL ENGINEERING) SEM-III

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/ WEEK	CREDITS	EXAMINATION		TOTAL MARKS
							INTERNAL	EXTERNAL	
1	MAJOR	MTME301	ADVANCED MACHINING PROCESS	4	2	6	90	60	150
2	MAJOR	MTME302	LEAN MANUFACTURING	4	2	6	90	60	150
3	MINOR	MTME303	MOOC/SWAYAM COURSE	3	0	3	100	00	100
4	VAC	MTME304	DISSERTATION PHASE-I	0	8	8	100	100	200
TOTAL				11	12	23	380	220	600

M. TECH (MECHANICAL ENGINEERING) SEM-IV

SR NO.	COURSE TYPE	COURSE CODE	COURSE NAME	LECTURE (HRS.)/ WEEK	PRACTICAL (HRS.)/ WEEK	CREDITS	EXAMINATION		TOTAL MARKS
							INTERNAL	EXTERNAL	
1	MAJOR	MTME401	INDUSTRY SEMINARS/WORKSHOPS/INTERNSHIP	0	2	2	50	00	50
2	MINOR	MTME402	COMPREHENSIVE VIVA VOCE	0	2	2	50	00	50
3	MAJOR	MTME403	DISEERTATION PHASE-II	0	16	16	200	200	400
4	VAC	MTME404	BUSINESS COMMUNICATION-II	2	0	2	00	50	50
TOTAL				2	20	22	300	250	550

SEMESTER-I

SUBJECT CODE: MTME101

SUBJECT NAME: ADVANCED MATHEMATICS FOR ENGINEERS

Course Objectives:

- To provide a rigorous mathematical foundation for advanced engineering modeling and analysis.
- To bridge theoretical mathematics with practical engineering applications.
- To develop problem-solving skills using analytical and computational tools.
- To prepare students for research and development in engineering domains requiring mathematical sophistication.

Course Outcomes: At the end of the course students shall be able to

CO1	Formulate and solve engineering problems using advanced techniques in linear algebra and tensor analysis.
CO2	Apply partial differential equations (PDEs) and transform methods to model dynamical systems and boundary value problems.
CO3	Use variational calculus and optimization methods for engineering design and control problems.
CO4	Analyze stochastic systems and uncertainty propagation using probability theory and statistical methods.

Unit	Content	Credit	Weightage
I	**Advanced Linear Algebra & Tensors for Engineers** ○ Review of vector spaces, eigenvalues, SVD, Jordan form ○ Matrix decompositions (LU, QR, Cholesky, Schur) ○ Tensor algebra: notation, operations, invariants ○ Tensor applications: stress-strain, inertia, constitutive models ○ Numerical linear algebra (conditioning, iterative solvers) • **Applications:** Structural analysis, continuum mechanics, control systems, data compression.	1	25%
II	**Partial Differential Equations & Transform Methods** ○ Classification of PDEs (elliptic, parabolic, hyperbolic) ○ Separation of variables, eigenfunction expansions ○ Green's functions for ODEs and PDEs ○ Integral transforms (Fourier, Laplace, Hankel) for PDEs ○ Introduction to finite element and finite volume concepts	1	25%

	• **Applications:** Heat transfer, wave propagation, fluid dynamics, signal processing.		
III	**Calculus of Variations & Optimization** ○ Functional derivatives, Euler–Lagrange equation ○ Constraints (Lagrange multipliers, isoperimetric problems) ○ Direct methods (Ritz, Galerkin) ○ Optimal control theory (Pontryagin's principle, Hamiltonian formulation) ○ Convex optimization basics (gradient descent, KKT conditions) • **Applications:** Optimal design, trajectory optimization, energy minimization, control systems.	1	25%
IV	**Stochastic Processes & Uncertainty Quantification** ○ Probability spaces, random variables, distributions ○ Stochastic processes (Brownian motion, Poisson process, Markov chains) ○ Itô calculus basics (stochastic differential equations) ○ Uncertainty quantification (Monte Carlo, polynomial chaos, sensitivity analysis) ○ Statistical estimation and regression for engineering data • **Applications:** Risk analysis, reliability engineering, random vibrations, financial engineering, signal noise modeling	1	25%

TEXT BOOKS:

- Kreyszig, E. – *Advanced Engineering Mathematics* (10th ed.) – Wiley.
- Strang, G. – *Linear Algebra and Its Applications* (5th ed.) – Cengage.
- Arfken, G.B., Weber, H.J., Harris, F.E. – *Mathematical Methods for Physicists* (7th ed.) – Academic Press.
- J.N. Reddy – *Applied Functional Analysis and Variational Methods in Engineering* – McGraw-Hill.
- Papoulis, A., & Pillai, S.U. – *Probability, Random Variables and Stochastic Processes* (4th ed.) – McGraw-Hill.

REFERENCE BOOKS:

- Riley, K.F., Hobson, M.P., Bence, S.J. – *Mathematical Methods for Physics and Engineering* (3rd ed.) – Cambridge.
- Gelfand, I.M., & Fomin, S.V. – *Calculus of Variations* – Dover.
- Oksendal, B. – *Stochastic Differential Equations: An Introduction with Applications* (6th ed.) – Springer.
- Holmes, M.H. – *Introduction to Numerical Methods in Differential Equations* – Springer.
- Gould, P. – *Introduction to Linear Elasticity* (for tensor applications) – Springer.

ONLINE RESOURCES:

- Coursera:
  - *Mathematics for Engineers Specialization* (The Hong Kong University of Science and Technology)
  - *Data Science Math Skills* (Duke University)

SUBJECT CODE: MTME102

SUBJECT NAME: ADVANCED MECHANICS OF SOLIDS

Course Objectives:

- To develop a rigorous, three-dimensional understanding of stress, strain, and constitutive material behavior.
- To provide the theoretical foundation for solving complex, real-world structural integrity problems.
- To bridge classical theory with modern applications in composites, plasticity, and computational mechanics.
- To prepare students for research and advanced design in aerospace, automotive, biomechanics, and material science.

Course Outcomes: At the end of the course students shall be able to

CO1	Apply tensor mathematics to formulate and analyze three-dimensional states of stress and strain in deformable bodies.
CO2	Formulate and solve boundary value problems in linear elasticity for various engineering geometries and loading conditions.
CO3	Analyze failure in materials using advanced yield and fracture criteria and apply principles of plasticity to model post-yield behavior.
CO4	Model and analyze specialized problems including anisotropic/composite materials, contact mechanics, and energy methods for structural analysis.

Unit	Content	Credit	Weightage
I	**Foundations of Continuum Mechanics & Linear Elasticity** • **Topics:** ○ Tensor algebra and calculus: index notation, transformations. ○ Analysis of stress: Cauchy stress tensor, principal stresses, invariants, equilibrium equations. ○ Analysis of strain: deformation gradient, strain tensors (Green-Lagrange, infinitesimal), compatibility conditions. ○ Generalized Hooke's Law for anisotropic, orthotropic, and isotropic materials. ○ Formulation of 3D elasticity: Navier's equations, Beltrami-Michell compatibility equations. • **Applications:** Stress analysis in machine components, foundations of Finite Element	1	25%

<table>
<tr><td></td><td>Analysis (FEA).</td><td></td><td></td></tr>
<tr><td>II</td><td>Analytical Methods & Failure Theories
Topics:
Solution strategies in elasticity: Saint-Venant’s principle, plane stress/strain, Airy stress function.
Torsion of non-circular sections (Prandtl’s membrane analogy).
Bending of curved beams and asymmetric sections.
Classical failure criteria: Tresca (max shear stress), von Mises (distortion energy).
Advanced failure and fracture criteria: Coulomb-Mohr, Drucker-Prager, introduction to Linear Elastic Fracture Mechanics (LEFM).
Applications: Shaft design, pressure vessels, crane hooks, failure prediction in ductile/brittle materials.</td><td>1</td><td>25%</td></tr>
<tr><td>III</td><td>Introduction to Plasticity & Advanced Material Models
Topics:
Phenomenology of plastic deformation: yield surface, hardening rules (isotropic, kinematic).
Stress-strain relations in plasticity: flow rule (associated, non-associated), Prandtl-Reuss equations.
Limit analysis: upper and lower bound theorems.
Introduction to creep and viscoelasticity (Maxwell, Kelvin-Voigt models).
Micromechanics basics: rule of mixtures, effective properties of composites.
Applications: Metal forming analysis, crashworthiness, polymer/composite component design, high-temperature structures.</td><td>1</td><td>25%</td></tr>
<tr><td>IV</td><td>Energy Methods & Selected Advanced Topics
Topics:
Energy principles: virtual work, minimum potential energy, Castigliano’s theorems.
Introduction to computational mechanics: Rayleigh-Ritz method as a precursor to FEM.
Contact mechanics: Hertzian contact theory for spheres/cylinders.
Stability of structures: buckling of columns (Euler’s formula), introduction to elastic stability.</td><td>1</td><td>25%</td></tr>
</table>

	◦ Introduction to mechanics of functionally graded materials (FGMs) and smart materials. • **Applications:** Spring design, gear tooth contact, buckling of slender structures, design of advanced material systems.		

TEXT BOOKS:

- Fung, Y.C., and Tong, P. – *Classical and Computational Solid Mechanics* – World Scientific.
- Ugural, A.C., and Fenster, S.K. – *Advanced Strength and Applied Elasticity* (5th ed.) – Pearson.
- Lai, W.M., Rubin, D., and Krempl, E. – *Introduction to Continuum Mechanics* (4th ed.) – Butterworth-Heinemann.
- Boresi, A.P., and Schmidt, R.J. – *Advanced Mechanics of Materials* (6th ed.) – Wiley.

REFERENCE BOOKS:

- Timoshenko, S.P., and Goodier, J.N. – *Theory of Elasticity* (3rd ed.) – McGraw-Hill.
- Hill, R. – *The Mathematical Theory of Plasticity* – Oxford University Press.
- Mase, G.T., Smelser, R.E., and Mase, G.E. – *Continuum Mechanics for Engineers* (3rd ed.) – CRC Press.
- Barber, J.R. – *Elasticity* (4th ed.) – Springer. (Excellent for contact mechanics).
- Jones, R.M. – *Mechanics of Composite Materials* (2nd ed.) – Taylor & Francis.

ONLINE RESOURCES:

- edX / Coursera:
  1. *Mechanics of Materials* series (Georgia Tech)
  2. *Fundamentals of Continuum Mechanics* (IIT Bombay via NPTEL)
- NPTEL (India): Extensive video courses on *Advanced Solid Mechanics* and *Theory of Elasticity*.

PRACTICAL LIST:

- Stress/Strain Transformation Tool: Write a program to calculate principal stresses, max shear stress, and plot Mohr's circle for a general 3D state of stress.
- Cantilever Beam with Combined Loading: Analytical solution using elasticity (Airy stress function) and validation via FEA for stress concentration.
- Failure Analysis Project: Given a multi-axial stress state for a component (e.g., aircraft landing gear), predict failure using Tresca, von Mises, and Mohr-Coulomb criteria; compare results.
- Plasticity Simulation: Model a simple plane-strain compression/indentation problem using a 2D FEA package to visualize yield surface evolution and plastic strain distribution.
- Contact Stress Analysis: **Calculate Hertzian contact stresses for a sphere-on-plate configuration analytically and compare with FEA results.**
- Buckling Analysis: **Use the Rayleigh-Ritz method to approximate the critical buckling load of a column with variable cross-section; verify with FEA eigenvalue buckling analysis.**
- Composite Lamina Analysis: **Write code to determine effective elastic constants and failure loads for an orthotropic lamina using Classical Lamination Theory (CLT) basics.**

- Energy Method Application: **Use Castigliano's theorem to calculate deflections in a statically indeterminate frame; compare with FEA results.**

SUBJECT CODE: MTME103

SUBJECT NAME: RESEARCH METHDOLOGY AND TECHNICAL COMMUNICATION

Course Objectives:

- To equip engineering graduates with a structured approach to scientific inquiry and problem-solving.
- To develop proficiency in selecting and applying appropriate research methods for engineering investigations.
- To enhance technical communication skills for academia and industry.
- To foster an understanding of research ethics, scholarly publishing, and lifelong learning in research.

Course Outcomes: At the end of the course students shall be able to

CO1	Formulate a research problem, conduct systematic literature reviews, and develop a viable research proposal.
CO2	Design and execute appropriate research methodologies (experimental, numerical, analytical) with consideration for ethics and data integrity.
CO3	Apply statistical tools and software for data analysis, interpretation, and validation of research findings.
CO4	Produce high-quality technical documents (research papers, proposals, theses) and deliver effective technical presentations.

Unit	Content	Credit	Weightage
I	**Foundations of Engineering Research & Problem Formulation** • **Topics:** o Philosophy of research: inductive vs. deductive reasoning, scientific method in engineering. o Types of engineering research: fundamental, applied, experimental, computational, empirical. o Problem identification and formulation: research gap analysis. o Literature review strategies: databases (Scopus, Web of Science, IEEE Xplore), citation management tools (Zotero, Mendeley), critical analysis of literature. o Developing a research proposal: objectives, scope, significance, and work plan. • **Applications:** Thesis topic selection, grant proposal writing, project planning.	1	25%
II	**Research Design, Methods & Ethics** • **Topics:** o Research design: experimental, quasi-	1	25%

	experimental, case study, modeling & simulation. ○ Data collection methods: sensors, surveys, instrumentation, simulation outputs. ○ Design of Experiments (DoE): factorial design, Taguchi methods, response surface methodology. ○ Research ethics: plagiarism, fabrication/falsification, authorship, informed consent. ○ Ethical approval process and responsible conduct of research (RCR). • **Applications:** Planning a lab/field experiment, setting up a CFD/FEA study, survey design.		
III	**Data Analysis, Statistics & Software Tools** • **Topics:** ○ Data preprocessing: outlier detection, missing data, normalization. ○ Descriptive and inferential statistics: hypothesis testing (t-test, ANOVA), confidence intervals. ○ Regression analysis: linear, multiple, logistic. ○ Introduction to multivariate analysis and machine learning for engineering data. ○ Software tools: MATLAB/Python (NumPy, SciPy, pandas), R, MiniTab. ○ Data visualization principles: effective graphs, charts, and plots. • **Applications:** Analyzing experimental results, validating computational models, interpreting sensor data.	1	25%
IV	**Technical Communication & Research Dissemination** • **Topics:** ○ Structure of technical documents: research papers, theses, technical reports. ○ Writing strategies: clarity, conciseness, coherence, and argument development. ○ Graphical abstracts, data presentation, and table/figure design. ○ Oral presentations: conference talks, thesis defense, poster design. ○ Publication process: journal selection, peer review, responding to reviewers. ○ Intellectual Property Rights (IPR): patents, copyrights, licensing. ○ Research dissemination: repositories,	1	25%

	academic social networks (ResearchGate, LinkedIn), and impact metrics (h-index, citations). • **Applications:** Paper writing, thesis compilation, conference presentation, patent filing.		

TEXT BOOKS:

- Kothari, C.R. – *Research Methodology: Methods and Techniques* (4th ed.) – New Age International.
- Day, R.A., and Gastel, B. – *How to Write and Publish a Scientific Paper* (9th ed.) – Greenwood.
- Montgomery, D.C. – *Design and Analysis of Experiments* (10th ed.) – Wiley.
- Alley, M. – *The Craft of Scientific Writing* (4th ed.) – Springer.

REFERENCE BOOKS:

- Bordens, K.S., and Abbott, B.B. – *Research Design and Methods: A Process Approach* (11th ed.) – McGraw-Hill.
- Wallwork, A. – *English for Writing Research Papers* (2nd ed.) – Springer.
- Box, G.E.P., Hunter, J.S., and Hunter, W.G. – *Statistics for Experimenters* (2nd ed.) – Wiley.
- IEEE Author Center Guides – *IEEE Publication Services and Products Board*.
- Laplante, P.A. – *Technical Writing: A Practical Guide for Engineers and Scientists* – CRC Press.

ONLINE RESOURCES:

- edX Courses:
    1. *"Principles of Statistical Analysis"* (Microsoft)
    2. *"How to Write and Publish a Scientific Paper"* (KU Leuven)

SUBJECT CODE: MTME104

SUBJECT NAME: PRODUCT DESIGN AND DEVELOPMENT

Course Objectives:

- To provide a holistic understanding of the modern product development lifecycle from ideation to launch.
- To develop proficiency in using state-of-the-art design, simulation, and prototyping tools.
- To instill an understanding of concurrent engineering, cost analysis, and sustainable design practices.
- To prepare students for roles in R&D, product design engineering, and innovation management.

Course Outcomes: At the end of the course students shall be able to

CO1	Apply systematic product development processes (Stage-Gate, Agile, Design Thinking) to convert market needs into technical specifications.
CO2	Utilize advanced engineering tools (CAD/CAE, DFMA, FEA, GD&T) for concept generation, embodiment design, and virtual prototyping.
CO3	Integrate principles of Design for X (Manufacturing, Assembly, Sustainability, Cost) and systems engineering in product development.
CO4	Plan and execute prototype development, testing, validation, and manage the transition to production.

Unit	Content	Credit	Weightage
I	**Product Planning & Conceptual Design** • **Topics:** o Product Development Process: Overview of Stage-Gate, Agile, Spiral, and V-Models. o Identifying Customer Needs: Voice of Customer (VoC), surveys, interviews, Kano model. o Product Planning: Market analysis, QFD (House of Quality), establishing Product Design Specification (PDS). o Creative Concept Generation: Brainstorming, TRIZ, morphological charts, biomimetics. o Concept Selection: Pugh charts, weighted decision matrices, feasibility analysis. • **Applications:** Consumer electronics, automotive subsystems, medical devices, industrial equipment.	1	25%
II	**Embodiment Design & Engineering Analysis** • **Topics:** o Principles of Embodiment Design: Product architecture, modularity, standardization, industrial design integration. o Material Selection: Ashby charts, CES EduPack, multi-criteria decision making. o Advanced Engineering Analysis: Design optimization (topology, shape, size), FEA for design validation, fatigue analysis. o Tolerance Analysis: GD&T (Geometric Dimensioning & Tolerancing), statistical tolerancing, stack-up analysis. o Design for Manufacturing & Assembly (DFMA): Boothroyd-Dewhurst methodology, design guidelines for casting, molding, machining, additive manufacturing. • **Applications:** Lightweight structural design, precision components, design of assemblies.	1	25%
III	**Design for X (DFX) & Sustainable Design** • **Topics:** o Design for Sustainability (DFS): Life Cycle Assessment (LCA), circular economy principles, end-of-life strategies (reuse, recycle). o Design for Cost (DFC): Should-cost modeling, activity-based costing, value	1	25%

	engineering. ◦ Design for Reliability & Safety (DFR/DFS): FMEA (Failure Mode and Effects Analysis), fault tree analysis, reliability prediction. ◦ Human-Centered Design (HCD): Ergonomics, usability testing, user experience (UX) for physical products. ◦ Systems Engineering: Requirements flow-down, interface management, systems integration. • **Applications:** Eco-friendly products, cost-optimized designs, safety-critical systems, consumer ergonomics.		
IV	**Prototyping, Testing & Commercialization** • **Topics:** ◦ Prototyping Strategies: Rapid prototyping (3D Printing - FDM, SLA, SLS), functional prototypes, pilot production. ◦ Testing & Validation: Design of Experiments (DoE) for testing, accelerated life testing, regulatory & compliance testing (CE, FCC, ISO). ◦ Intellectual Property (IP) in Design: Patents, design patents, trade secrets, IP strategy. ◦ Project Management for NPD: Scheduling (Gantt charts, critical path), risk management, budgeting. ◦ Transition to Production: Supply chain coordination, design for supply chain, production ramp-up. **Applications:** New product launch, patent filing, prototype validation, production handoff.	1	25%

TEXT BOOKS:

- Ulrich, K.T., Eppinger, S.D., and Yang, M.C. – *Product Design and Development* (7th ed.) – McGraw-Hill.
- Dieter, G.E., and Schmidt, L.C. – *Engineering Design* (6th ed.) – McGraw-Hill.
- Ashby, M.F. – *Materials Selection in Mechanical Design* (6th ed.) – Butterworth-Heinemann.
- Pahl, G., Beitz, W., Feldhusen, J., and Grote, K.H. – *Engineering Design: A Systematic Approach* (3rd ed.) – Springer.

REFERENCE BOOKS:

- Boothroyd, G., Dewhurst, P., and Knight, W. – *Product Design for Manufacture and Assembly* (3rd ed.) – CRC Press.
- Otto, K., and Wood, K. – *Product Design: Techniques in Reverse Engineering and New Product Development* – Pearson.
- Braila, J.G. – *Handbook of Product Design for Manufacturing* – McGraw-Hill.

- Ulman, D.G. – *The Mechanical Design Process* (5th ed.) – McGraw-Hill.
- Gerhard, P. – *Design for Six Sigma+Lean Toolset* – Springer.

ONLINE RESOURCES:

- Coursera: *"Digital Manufacturing & Design Technology"* (University at Buffalo), *"Autodesk CAD/CAM/CAE"* Specialization.
- edX: *"Engineering Design for a Circular Economy"* (DelftX).
- Udemy: Courses on GD&T, DFMA, and SolidWorks simulation.

PRACTICAL LIST:

- Need Identification & PDS Development (Module 1):
  1. *Task:* Select a real-world problem (e.g., sustainable kitchen gadget, assistive device). Conduct VoC interviews, perform competitive benchmarking, and create a detailed Product Design Specification (PDS) document.
- Concept Generation & Selection with CAD Modeling (Module 1 & 2):
  1. *Task:* Generate 5 distinct conceptual solutions for the chosen problem using brainstorming/TRIZ. Develop 3D CAD models (in Fusion 360/SolidWorks) of the top 2 concepts. Perform a formal concept selection using a Pugh chart.
- Embodiment Design & DFMA/Simulation Exercise (Module 2 & 3):
  1. *Task:* Take the selected concept and develop a detailed embodiment design.
     1. Perform a DFMA analysis (manual or using software) to estimate part count and assembly time.
     2. Conduct a static FEA (e.g., in ANSYS Student) on a critical component and optimize its topology/ shape for weight reduction.
     3. Perform a tolerance stack-up analysis on a critical assembly.
- Sustainable Design & Prototyping Project (Module 3 & 4):
  1. *Task:* For the final design:
     1. Conduct a simplified Life Cycle Assessment (LCA) using OpenLCA to identify major environmental impacts.
     2. 3D print a scale or functional prototype of a key sub-assembly.
     3. Create a Project Plan (Gantt chart) for its development and a Patent Search report summarizing relevant prior art.
     4. Present the final product design in a formal design review, including a cost estimate and business case rationale.

SUBJECT CODE: MTME105

SUBJECT NAME: ENTERPRENURSHIP DEVELOPMENT

Course Objectives:

- To cultivate an entrepreneurial mindset among engineering graduates.
- To provide practical tools for transforming technical ideas into viable business ventures.
- To develop skills in business modeling, financial planning, and venture funding.
- To prepare students for startup creation, intrapreneurship, or technology commercialization roles.

Course Outcomes: At the end of the course students shall be able to

CO1	Identify and evaluate entrepreneurial opportunities emerging from technological trends and market gaps.

CO2	Develop a comprehensive business model and validate it using lean startup methodologies and customer discovery.
CO3	Create financial projections, evaluate startup costs, and understand funding mechanisms for technology ventures.
CO4	Formulate a complete investor-ready business plan and deliver an effective pitch to potential stakeholders.

Unit	Content	Credit	Weightage
I	**Entrepreneurial Mindset & Opportunity Identification** • **Topics:** ○ The Entrepreneurial Engineer: Mindset, traits, and role in economic development. ○ Sources of Innovation: Technology push vs. market pull, disruptive vs. sustaining innovation. ○ Opportunity Recognition: Identifying problems worth solving, trend analysis (STEEP), blue ocean strategy. ○ Idea Validation: Lean canvas, hypothesis testing, conducting problem-solution interviews. ○ Intellectual Property Strategy for Startups: Patents, trademarks, trade secrets, and licensing basics. • **Applications:** Spotting opportunities in cleantech, Industry 4.0, medtech, and digital transformation.	1	25%
II	**Business Model Design & Customer Development** • **Topics:** ○ Business Model Innovation: Business Model Canvas (Osterwalder), Value Proposition Canvas. ○ Customer Discovery & Validation: The "Get Out of the Building" approach, creating MVP (Minimum Viable Product). ○ Market Analysis: TAM, SAM, SOM, competitive analysis, positioning. ○ Pricing Strategies for Tech Products: Cost-plus, value-based, subscription, freemium models. ○ Go-to-Market Strategy: Sales channels, partnerships, digital marketing fundamentals. • **Applications:** Designing scalable models for SaaS, hardware-as-a-service, platform businesses.	1	25%

III	**Startup Finance, Funding & Legal Foundations**
	
	• **Topics:**
	  ○ Startup Financials: Building financial models, unit economics, burn rate, runway.
	  ○ Pro Forma Statements: Income statement, cash flow, balance sheet projections.
	  ○ Funding Sources: Bootstrapping, angels, venture capital, crowdfunding, government grants (SBIR, DST).
	  ○ Valuation Methods for Early-Stage Startups: Scorecard, Berkus, risk factor summation.
	  ○ Legal Structures & Compliance: Company registration (LLP, Pvt Ltd), shareholder agreements, ESOPs, compliance essentials.
	  ○ Term Sheet Fundamentals: Key clauses, negotiation basics.
	• **Applications:** Preparing for seed funding, managing cash flow, cap table management.
		1	25%

IV	**Business Planning, Pitching & Scaling Ventures**
	• **Topics:**
	  ○ The Business Plan: Executive summary, company description, product/service, market analysis, marketing plan, management team, financial projections.
	  ○ The Art of Pitching: Investor pitch deck structure, storytelling, demo preparation.
	  ○ Building the Team: Co-founder selection, hiring early employees, advisory boards.
	  ○ Operational Planning: Supply chain, quality, scaling production.
	  ○ Growth Strategies: Scaling challenges, pivoting, exit strategies (acquisition, IPO).
	  ○ Social Entrepreneurship & Ethics: Creating social impact, ethical leadership.
	• **Applications:** Crafting investor pitches, developing operational roadmaps, planning for scale.
		1	25%

TEXT BOOKS:

- Osterwalder, A., and Pigneur, Y. – *Business Model Generation* – Wiley.
- Ries, E. – *The Lean Startup* – Penguin.
- Blank, S., and Dorf, B. – *The Startup Owner's Manual* – K & S Ranch.
- Barrow, C., Barrow, P., and Brown, R. – *The Business Plan Workbook* (10th ed.) – Kogan Page.

REFERENCE BOOKS:

- Aulet, B. – *Disciplined Entrepreneurship* – Wiley.

- Mullins, J. – *The New Business Road Test* (5th ed.) – FT Publishing.
- Kawasaki, G. – *The Art of the Start 2.0* – Portfolio Penguin.
- Thiel, P. – *Zero to One* – Crown Business.
- Maurya, A. – *Running Lean* (2nd ed.) – O'Reilly.

ONLINE RESOURCES:

- Coursera: *"Entrepreneurship Specialization"* (Wharton), *"Startup Entrepreneurship"* (Technion).
- edX: *"Entrepreneurship in Emerging Economies"* (HarvardX), *"Innovation and Entrepreneurship"* (DelftX).
- Udemy: Courses on Business Plan Writing, Startup Funding, and Digital Marketing.

SEMESTER-II

SUBJECT CODE: MTME201

SUBJECT NAME: ADVANCED DYNAMICS AND VIBRATIONS

Course Objectives:

- To provide a strong theoretical foundation in analytical dynamics for complex engineering systems.
- To develop proficiency in analyzing both linear and nonlinear vibratory systems.
- To introduce modern topics in dynamics including chaos, random vibrations, and active control.
- To equip students with skills applicable to aerospace, automotive, robotics, and structural dynamics.

Course Outcomes: At the end of the course students shall be able to

CO1	Formulate equations of motion for complex mechanical systems using Lagrangian and Hamiltonian mechanics.
CO2	Analyze and solve multi-degree-of-freedom (MDOF) and continuous systems using modal analysis and approximate methods.
CO3	Apply advanced vibration concepts including random vibrations, nonlinear dynamics, and vibration control techniques.
CO4	Utilize computational tools (MATLAB, Simulink) to simulate, analyze, and visualize dynamic and vibratory responses.

Unit	Content	Credit	Weightage
I	**Analytical Dynamics** • **Topics:** ○ Review of Newton-Euler formulation for rigid bodies. ○ Variational principles: D'Alembert's principle, Hamilton's principle. ○ Lagrangian dynamics: Generalized coordinates, constraints (holonomic/nonholonomic), Lagrange's equations. ○ Hamiltonian mechanics: Canonical equations, phase space, integrals of motion. ○ Dynamics of non-inertial systems: Coriolis and centrifugal effects. • **Applications:** Spacecraft attitude dynamics, robotic manipulators, multi-body systems.	1	25%
II	**Advanced Linear Vibrations** • **Topics:** ○ Multi-degree-of-freedom (MDOF) systems: Matrix formulation, eigenvalue problem, orthogonality of modes.	1	25%

	○ Modal analysis: Decoupling equations of motion, modal superposition, response to harmonic, periodic, and transient excitations. ○ Damping models: Proportional damping, Rayleigh damping, non-proportional damping, complex modes. ○ Continuous systems: Exact solutions for bars, beams, and membranes; natural frequencies and mode shapes. ○ Approximate methods: Rayleigh-Ritz, Assumed Modes, Galerkin's method. • **Applications:** Vehicle suspension systems, building vibrations, turbine blade dynamics.		
III	**Nonlinear Dynamics & Random Vibrations** • **Topics:** ○ Introduction to nonlinear systems: Sources of nonlinearity (geometric, material, damping). ○ Qualitative analysis: Phase plane, equilibrium points, stability (Lyapunov methods). ○ Approximate analytical methods: Perturbation methods, method of averaging. ○ Chaotic dynamics: Introduction, strange attractors, Poincaré maps. ○ Random vibrations: Random process theory, correlation, spectral density. ○ Response of linear systems to random excitation: Single and multi-DOF. • **Applications:** MEMS devices, nonlinear isolators, chaotic pendulums, wind/earthquake excitation of structures.	1	25%
IV	**Specialized Topics & Advanced Applications** • **Topics:** ○ Rotor dynamics: Jeffcott rotor model, critical speeds, gyroscopic effects, stability analysis. ○ Vibration control: Passive (absorbers, isolators), active, and semi-active control strategies. ○ Vibration measurement and signal processing: FFT, frequency response functions, experimental modal analysis. ○ Introduction to wave propagation in	1	25%

	continuous media. ◦ Numerical integration methods for dynamics: Newmark, Runge-Kutta. • **Applications:** Turbo-machinery, automotive NVH, seismic isolation, smart structures.		

TEXT BOOKS:

- Meirovitch, L. – *Fundamentals of Vibrations* – McGraw-Hill.
- Greenwood, D.T. – *Advanced Dynamics* – Cambridge University Press.
- Rao, S.S. – *Mechanical Vibrations* (6th ed.) – Pearson.
- Thomson, W.T., and Dahleh, M.D. – *Theory of Vibrations with Applications* (5th ed.) – Pearson.

REFERENCE BOOKS:

- Inman, D.J. – *Engineering Vibration* (5th ed.) – Pearson.
- Nayfeh, A.H., and Mook, D.T. – *Nonlinear Oscillations* – Wiley.
- Craig, R.R., and Kurdila, A.J. – *Fundamentals of Structural Dynamics* (2nd ed.) – Wiley.
- Newland, D.E. – *Random Vibrations, Spectral & Wavelet Analysis* – Dover.
- Goldstein, H., Poole, C., and Safko, J. – *Classical Mechanics* (3rd ed.) – Pearson.

ONLINE RESOURCES:

- Coursera: *"Dynamics and Control"* (University of Pennsylvania), *"Mechanical Behavior of Materials"* (Georgia Tech).
- edX: *"Structural Dynamics"* (MITx), *"Dynamics"* (MITx).
- NPTEL (India): Extensive video courses on *Mechanical Vibrations* (Prof. S. K. Dwivedy) and *Advanced Dynamics*.

SUBJECT CODE: MTME202

SUBJECT NAME: REFRIGERATION AND CRYOGENICS

Course Objectives:

- To provide an in-depth understanding of advanced refrigeration systems and cryogenic engineering.
- To develop proficiency in the design and analysis of low-temperature thermodynamic cycles.
- To address environmental challenges through the study of alternative refrigerants and sustainable technologies.
- To prepare students for careers in HVAC&R, LNG, aerospace cooling, superconductivity, and food preservation industries.

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze and optimize advanced vapor compression and absorption refrigeration cycles using exergy and energy methods.
CO2	Design and evaluate low-temperature systems, including cascade, mixed refrigerant, and cryogenic cycles.
CO3	Select appropriate refrigerants considering thermodynamic, environmental, and safety properties.
CO4	Apply principles of cryogenic engineering to systems like liquefaction, storage, and superconducting applications.

Unit	Content	Credit	Weightage

I	**Advanced Refrigeration Systems & Cycle Analysis**
	• **Topics:**
	  ○ Review of basic vapor compression cycle: Limitations and improvements.
	  ○ Multi-stage and cascade refrigeration systems: Design, analysis, applications.
	  ○ Absorption refrigeration: LiBr-H_2O and NH_3-H_2O systems, performance evaluation.
	  ○ Transcritical CO_2 cycles: Applications in commercial refrigeration and heat pumps.
	  ○ Exergy analysis of refrigeration cycles: Irreversibility, exergy destruction, optimization.
	• **Applications:** Cold storage, industrial process cooling, supermarket refrigeration.
		1	25%

II	**Refrigerants, Components & System Design**
	• **Topics:**
	  ○ Refrigerants: Thermodynamic and transport properties, environmental impact (ODP, GWP, TEWI).
	  ○ Natural refrigerants: CO_2, ammonia, hydrocarbons, water.
	  ○ Advanced components: Compressors (scroll, screw, centrifugal), electronic expansion valves, microchannel heat exchangers.
	  ○ System simulation and design: Use of software (CoolPack, REFPROP, EES).
	  ○ Heat exchanger design for refrigeration: Condensers, evaporators, suction line heat exchangers.
	• **Applications:** Selection for low-GWP systems, component matching, efficiency improvement.
		1	25%

III	**Cryogenic Fundamentals & Gas Liquefaction**
	• **Topics:**
	  ○ Properties of materials at low temperatures: Thermal, mechanical, electrical.
	  ○ Insulation systems: Vacuum, multilayer, perlite, aerogel.
	  ○ Gas liquefaction cycles: Linde-Hampson, Claude, Collins, Brayton cycles.
	  ○ Mixed refrigerant cycles (MRCs): For LNG and air separation.
		1	25%

	◦ Cryocoolers: Stirling, Gifford-McMahon, pulse tube, Joule-Thomson coolers. • **Applications:** LNG production, industrial gas manufacturing (O_2, N_2, Ar), space applications.		
IV	**Cryogenic Applications & Emerging Technologies** • **Topics:** ◦ Cryogenic storage and transport: Dewars, cryostats, pipelines. ◦ Superconductivity and its applications: MRI, Maglev, SMES. ◦ Aerospace cryogenics: Cryogenic fuel (LH_2/LOX) management for rockets. ◦ Food freeze-drying and cryopreservation in biotech. ◦ Magnetic refrigeration and thermoacoustic refrigeration principles. ◦ Sustainability in refrigeration: Waste heat recovery, solar-powered systems, integrated energy systems. • **Applications:** Medical imaging, space technology, food processing, sustainable cooling.	1	25%

TEXT BOOKS:

- Stoecker, W.F., and Jones, J.W. – *Refrigeration and Air Conditioning* (2nd ed.) – McGraw-Hill.
- Barron, R.F. – *Cryogenic Systems* (2nd ed.) – Oxford University Press.
- Timmerhaus, K.D., and Flynn, T.M. – *Cryogenic Process Engineering* – Springer.
- Dossat, R.J., and Horan, T.J. – *Principles of Refrigeration* (5th ed.) – Pearson.

REFERENCE BOOKS:

- ASHRAE Handbook – *Refrigeration* (Latest Edition) – ASHRAE.
- Mullan, W., and Kropscott, B. – *Cryogenic Engineering: Fifty Years of Progress* – Springer.
- Arora, C.P. – *Refrigeration and Air Conditioning* (4th ed.) – McGraw-Hill.
- Walker, G. – *Cryocoolers* (Parts 1 & 2) – Springer.
- Granryd, E., et al. – *Refrigerating Engineering* – KTH Publication.

ONLINE RESOURCES:

- Coursera: *"Air Conditioning Systems"* (University of Colorado), *"Thermodynamics"* (University of Michigan).
- edX: *"Sustainable Energy: Design a Renewable Future"* (DelftX).
- NPTEL (India): *"Cryogenic Engineering"* (IIT Kharagpur), *"Refrigeration and Air Conditioning"* (IIT Roorkee).

PRACTICAL LIST:

1. Cycle Analysis & Optimization using EES/REFPROP (Module 1):
   - *Task:* Model a two-stage cascade refrigeration system. Perform energy and exergy analysis. Optimize intermediate pressure for maximum COP. Compare with a single-stage

system.

2. Refrigerant Selection & Heat Exchanger Sizing Project (Module 2):
   - *Task:* For a given application (e.g., a dairy chiller), select a low-GWP refrigerant. Design a microchannel evaporator using appropriate correlations. Simulate its performance under part-load conditions using a simplified model.
3. Cryogenic Liquefaction Cycle Design (Module 3):
   - *Task:* Design a simplified Linde-Hampson cycle for nitrogen liquefaction. Calculate the figure of merit (FOM), liquid yield, and compressor work. Perform a sensitivity analysis on key parameters (inlet pressure, heat exchanger effectiveness).
4. Cryogenic Storage & Emerging Tech Case Study (Module 4):
   - *Task:*
     1. Part A: Design the insulation system for a liquid nitrogen storage dewar. Calculate boil-off rate and total heat ingress.
     2. Part B: Conduct a feasibility study comparing a conventional vapor compression system with a magnetic refrigeration system for a specific small-scale application (e.g., wine cooler). Consider efficiency, cost, and environmental impact.

SUBJECT CODE: MTME203

SUBJECT NAME: COMBUSTION ENGINEERING

Course Objectives:

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze combustion thermodynamics, chemical equilibrium, and flame propagation mechanisms.
CO2	Model and simulate chemically reacting flows using conservation equations and kinetic mechanisms.
CO3	Design and evaluate practical combustion systems (IC engines, gas turbines, furnaces) for efficiency and emissions.
CO4	Apply computational tools (ANSYS Chemkin, CFD) for combustion simulation and pollutant formation analysis.

Unit	Content	Credit	Weightage
I	**Combustion Fundamentals & Chemical Kinetics** • **Topics:** ○ Thermodynamics of reacting systems: Adiabatic flame temperature, chemical equilibrium. ○ Chemical kinetics: Elementary reactions, reaction rates, Arrhenius law, chain reactions. ○ Combustion chemistry of hydrocarbons: Oxidation mechanisms for C1-C4 fuels. ○ Introduction to combustion waves: Deflagration vs. detonation, Hugoniot relations.	1	25%

	◦ Laminar premixed flames: Flame speed, quenching, flammability limits. • **Applications:** Burner design, explosion safety, fuel characterization.		
II	**Turbulent Combustion & Spray Combustion** • **Topics:** ◦ Turbulence-chemistry interaction: Regimes of turbulent combustion (Borghi diagram). ◦ Turbulent combustion models: Eddy breakup, flamelet, PDF methods. ◦ Droplet evaporation and combustion: d^2-law, multi-component fuels. ◦ Spray formation and characterization: Atomization, breakup models. ◦ Two-phase reacting flows: Coal particle combustion, solid propellants. • **Applications:** Gas turbine combustors, diesel engines, rocket motors.	1	25%
III	**Combustion Systems & Emissions** • **Topics:** ◦ Internal Combustion Engines: SI engine combustion (knock), CI engine combustion (ignition delay, mixing-controlled). ◦ Gas turbine combustion: Lean premixed pre-vaporized (LPP) combustion, RQL (Rich-Quench-Lean) combustors. ◦ Industrial furnaces and boilers: Swirl burners, low-NOx burners. ◦ Pollutant formation: NOx (thermal, prompt, fuel), SOx, soot, CO, unburnt hydrocarbons. ◦ Emission control technologies: Catalytic converters, SCR, DPF, combustion modification. • **Applications:** Automotive engines, power plants, industrial heating.	1	25%
IV	**Advanced Topics & Alternative Fuels** • **Topics:** ◦ Alternative fuels: Hydrogen, syngas, biofuels, ammonia combustion. ◦ Combustion instability: Thermoacoustic oscillations, Rayleigh criterion, control strategies. ◦ Low-temperature combustion: HCCI, RCCI, MILD combustion. ◦ Numerical combustion: Introduction to ANSYS Fluent/CFX with combustion modules, OpenFOAM reacting flow solvers.	1	25%

	◦ Diagnostics: Laser-based techniques (LIF, PIV), emission spectroscopy. ◦ Carbon capture in combustion systems: Oxy-fuel combustion, chemical looping. • **Applications:** Renewable fuel utilization, next-generation engines, carbon-neutral power.		

TEXT BOOKS:

- Turns, S.R. – *An Introduction to Combustion: Concepts and Applications* (4th ed.) – McGraw-Hill.
- Glassman, I., Yetter, R.A., and Glumac, N.G. – *Combustion* (5th ed.) – Academic Press.
- Warnatz, J., Maas, U., and Dibble, R.W. – *Combustion: Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation* (5th ed.) – Springer.
- Lefebvre, A.H., and Ballal, D.R. – *Gas Turbine Combustion: Alternative Fuels and Emissions* (3rd ed.) – **CRC Press.**

REFERENCE BOOKS:

- Heywood, J.B. – *Internal Combustion Engine Fundamentals* (2nd ed.) – McGraw-Hill.
- Law, C.K. – *Combustion Physics* – Cambridge University Press.
- Peters, N. – *Turbulent Combustion* – Cambridge University Press.
- Kuo, K.K., and Acharya, R. – *Fundamentals of Turbulent and Multi-Phase Combustion* – Wiley.
- Kohse-Höinghaus, K., and Jeffries, J.B. – *Applied Combustion Diagnostics* – Taylor & Francis.

ONLINE RESOURCES:

- Coursera: *"Combustion"* (University of Colorado), *"Introduction to Engineering Combustion"* (University of Michigan).
- edX: *"Energy Production, Distribution & Safety"* (MITx).
- NPTEL (India): *"Combustion"* (IIT Madras), *"IC Engines"* (IIT Kharagpur).

PRACTICAL LIST:

1. Chemical Kinetics & Equilibrium Analysis using Cantera/Chemkin (Module 1):
   - *Task:* Simulate a perfectly stirred reactor (PSR) for methane-air combustion. Calculate ignition delay times and adiabatic flame temperatures for different equivalence ratios. Plot species concentrations vs. time and analyze major reaction pathways.
2. Laminar Flame Speed & Emissions Prediction (Module 1 & 3):
   - *Task:* Using a detailed kinetic mechanism (e.g., GRI-Mech), compute laminar flame speeds for a syngas (H_2/CO) mixture. Investigate the effect of pressure and temperature. Predict NO formation using post-processing.
3. Spray Combustion Modeling in a Simplified Combustor (Module 2):
   - *Task:* Set up a 2D axisymmetric CFD simulation (in ANSYS Fluent/OpenFOAM) of a liquid fuel spray in a model combustor. Use a discrete phase model (DPM) with evaporation. Analyze droplet trajectories, vapor distribution, and flame structure.
4. IC Engine Combustion & Emissions Case Study (Module 3 & 4):

- *Task:*
    1. Part A: Perform a zero-dimensional thermodynamic simulation of an SI engine cycle (using software like GT-POWER or a MATLAB model) to study the effect of compression ratio and EGR on efficiency and NOx.
    2. Part B: Conduct a comparative study of two alternative fuels (e.g., ethanol vs. methanol) for the same engine, analyzing performance, combustion phasing, and emission trade-offs.

SUBJECT CODE: MTME204

SUBJECT NAME: ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

Course Objectives:

- To equip mechanical engineers with practical AI/ML skills directly applicable to industry and research.
- To demonstrate the integration of data-driven methods with traditional physics-based engineering approaches.
- To develop proficiency in using Python's ML ecosystem for solving real-world mechanical engineering problems.
- To foster an understanding of the complete ML pipeline from data acquisition to model deployment.

Course Outcomes: At the end of the course students shall be able to

CO1	Formulate mechanical engineering problems as supervised and unsupervised learning tasks.
CO2	Implement and evaluate classical ML models for regression, classification, and clustering tasks on engineering datasets.
CO3	Design and train deep neural networks for computer vision, time-series analysis, and generative modeling in engineering contexts.
CO4	Apply AI/ML to core mechanical domains: predictive maintenance, design optimization, additive manufacturing, and autonomous systems.

Unit	Content	Credit	Weightage
I	**Foundations & Classical Machine Learning for Engineering** • **Topics:** ○ Introduction to AI/ML in Mechanical Engineering: Digital twins, Industry 4.0, smart manufacturing. ○ Python for ML: NumPy, Pandas, Scikit-learn, basic visualization (Matplotlib, Seaborn). ○ Data Preprocessing for Engineering Data: Handling sensor data, missing values, normalization, feature engineering. ○ **Supervised Learning:** Linear/Logistic Regression, Decision Trees, Random Forests, Support Vector Machines.	1	25%

	◦ **Unsupervised Learning:** K-Means, Hierarchical Clustering, PCA for dimensionality reduction. ◦ Model Evaluation: Cross-validation, hyperparameter tuning, metrics (MSE, MAE, accuracy, precision, recall). • **Applications:** Quality prediction in manufacturing, fault classification, customer segmentation.		
II	**Deep Learning Fundamentals & Computer Vision for Engineering** • **Topics:** ◦ Neural Networks: Perceptrons, activation functions, backpropagation. ◦ Deep Learning Frameworks: PyTorch/TensorFlow basics. ◦ **Convolutional Neural Networks (CNNs):** Architecture, pooling, transfer learning. ◦ Computer Vision for Mechanical Systems: Image classification, object detection (YOLO, Faster R-CNN), semantic segmentation (U-Net). ◦ **Recurrent Neural Networks (RNNs) & LSTMs:** For sequential data. ◦ Time-Series Forecasting with DL: Multivariate forecasting, sequence-to-sequence models. • **Applications:** Visual inspection (welding, defects), predictive maintenance from sensor logs, thermal image analysis.	1	25%
III	**Advanced Topics & Generative AI for Engineering Design** • **Topics:** ◦ **Generative Models:** Variational Autoencoders (VAEs) and Generative Adversarial Networks (GANs). ◦ AI for Design & Optimization: Surrogate modeling, topology optimization with ML, generative design. ◦ Reinforcement Learning (RL) Basics: Markov Decision Processes, Q-Learning, policy gradients. ◦ RL for Control & Robotics: Applications in autonomous systems and dynamic control.	1	25%

	◦ **Explainable AI (XAI):** SHAP, LIME for interpreting model predictions in critical engineering decisions. ◦ **Graph Neural Networks (GNNs):** Introduction for materials science and complex systems. • **Applications:** Novel structure generation, material discovery, adaptive control policies, interpretable fault diagnosis.		
IV	**ML Systems & Specialized Mechanical Engineering Applications** • **Topics:** ◦ **ML Operations (MLOps) for Engineers:** Model deployment (Flask/Docker), versioning (MLflow), monitoring. ◦ **Physics-Informed Neural Networks (PINNs):** Integrating governing equations (PDEs) with neural networks. ◦ **Digital Twins & Prognostics:** Building data-driven digital twins, remaining useful life (RUL) prediction. ◦ **AI in Additive Manufacturing:** Process parameter optimization, defect prediction in 3D printing. ◦ **Smart Materials & IoT:** Federated learning for edge devices in mechanical systems. ◦ **Ethics, Bias, and Safety:** Responsible AI in safety-critical mechanical systems. • **Applications:** Live dashboards for predictive maintenance, simulating fluid flows with PINNs, optimizing AM builds.	1	25%

TEXT BOOKS:

- Géron, A. – *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow* (3rd ed.) – O'Reilly.
- Goodfellow, I., Bengio, Y., and Courville, A. – *Deep Learning* – MIT Press.
- Murphy, K.P. – *Probabilistic Machine Learning: An Introduction* – MIT Press.
- Aggarwal, C.C. – *Neural Networks and Deep Learning: A Textbook* – Springer.

REFERENCE BOOKS:

- Raschka, S., and Mirjalili, V. – *Python Machine Learning* (4th ed.) – Packt.
- Zhang, A., Lipton, Z.C., Li, M., and Smola, A.J. – *Dive into Deep Learning* – Cambridge University Press.
- Brunton, S.L., and Kutz, J.N. – *Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control* – Cambridge University Press.
- Bishop, C.M. – *Pattern Recognition and Machine Learning* – Springer.

ONLINE RESOURCES:

- Coursera: *"Machine Learning"* (Andrew Ng), *"Deep Learning Specialization"*.
- edX: *"MITx: Machine Learning with Python"*, *"ColumbiaX: AI for Engineers"*.
- Practical deep learning courses.

PRACTICAL LIST:

1. Predictive Maintenance with Classical ML (Module 1):
   - *Task:* Use the NASA Turbofan Engine Degradation Simulation Dataset. Perform exploratory data analysis, engineer features from sensor time-series, and train a Random Forest/ Gradient Boosting model to predict Remaining Useful Life (RUL). Compare with a simple regression baseline.
2. Visual Defect Detection with CNNs (Module 2):
   - *Task:* Using a dataset like NEU surface defect database (steel surface defects) or casting product image data, build a CNN classifier to identify defect types. Implement data augmentation and use transfer learning (ResNet/VGG). Deploy the model as a simple web app using Flask/Gradio.
3. Generative Design with VAEs/GANs (Module 3):
   - *Task:* Train a Variational Autoencoder (VAE) on a dataset of 2D mechanical structures (e.g., truss designs represented as images or graphs). Use the latent space to interpolate between designs and generate novel, valid structures. Evaluate output feasibility with a simple physics-based checker.
4. End-to-End MLOps Project: Digital Twin Lite (Module 4):
   - *Task:*
     1. Part A: Create a Physics-Informed Neural Network (PINN) to solve the 1D steady-state heat conduction equation, comparing its solution to the analytical result.
     2. Part B: Develop a pipeline that ingests live sensor data (simulated via a script), runs a pre-trained fault detection model, logs predictions using MLflow, and triggers an alert (email/ dashboard) upon anomaly detection.

SEMESTER-III

SUBJECT CODE: MTME301

SUBJECT NAME: ADVANCED MACHINING PROCESSES

Course Objectives:

- To provide an in-depth understanding of advanced material removal mechanisms beyond traditional cutting.
- To develop expertise in process selection, parameter optimization, and quality control for high-value manufacturing.
- To explore hybrid and emerging machining technologies for next-generation manufacturing challenges.
- To prepare students for careers in aerospace, automotive, medical device, and tooling industries.

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze the principles, capabilities, and limitations of conventional and non-conventional machining processes.
CO2	Select appropriate advanced machining processes for difficult-to-machine materials (superalloys, composites, ceramics).
CO3	Model and optimize machining parameters using statistical and computational methods to enhance productivity and surface integrity.
CO4	Design and plan machining operations for precision, micro, and nano-machining applications.

Unit	Content	Credit	Weightage
I	**Precision & Ultra-Precision Machining** • **Topics:** ○ Fundamentals of machining: Chip formation, forces, temperature, tool wear mechanisms. ○ Precision machining: Diamond turning, micro-milling, ultra-precision grinding. ○ Machine tool metrology: Laser interferometry, CMMs, surface roughness analysis. ○ Thermal effects and error compensation in precision machining. ○ Machining of brittle materials: Ductile-regime machining of glasses and ceramics. • **Applications:** Optical components, silicon wafers, medical implants, mold/die manufacturing.	1	25%
II	**Non-Traditional Machining (NTM) Processes** • **Topics:** ○ **Electro-Discharge Machining (EDM):** Die-sinking, wire-EDM, micro-EDM, process parameters. ○ **Electrochemical Machining (ECM) & Electrochemical Grinding**	1	25%

	(ECG): Principles, tool design, applications. ◦ **Laser Beam Machining (LBM):** Nd:YAG, CO_2, femtosecond lasers for cutting, drilling, texturing. ◦ **Abrasive Water Jet Machining (AWJM):** Process mechanics, nozzle design, multi-material cutting. ◦ **Ultrasonic Machining (USM):** Tool design, abrasive slurry, hybrid processes. • **Applications:** Turbine blade cooling holes, aerospace components, fuel injector nozzles, hardened tool steels.		
III	**Hybrid & Advanced Cutting Processes** • **Topics:** ◦ **High-Speed Machining (HSM):** Dynamics, toolpath strategies, machine tool requirements. ◦ **Hard Machining:** Machining of hardened steels (>45 HRC) with PCBN and ceramic tools. ◦ **Vibration-Assisted Machining (VAM):** 1D and 2D vibrations for improved chip breaking and surface finish. ◦ **Cryogenic Machining:** Liquid nitrogen cooling for Ti and Ni alloys. ◦ **Minimum Quantity Lubrication (MQL) & Dry Machining:** Sustainable machining strategies. • **Applications:** Aerospace structural components, automotive powertrains, green manufacturing.	1	25%
IV	**Process Modeling, Monitoring & Industry 4.0 Integration** • **Topics:** ◦ Machining process modeling: Analytical, numerical (FEA), and empirical approaches. ◦ Design of Experiments (DOE) and statistical optimization (Taguchi, RSM). ◦ Tool condition monitoring: Acoustic emission, force, vibration sensors, and AI-based prediction. ◦ Digital twin for machining: Virtual process simulation, predictive maintenance. ◦ Micro/nano-fabrication: Focused ion beam (FIB), micro-electrodischarge, nanometric cutting.	1	25%

	◦ Sustainability in machining: Energy consumption, carbon footprint, circular economy. • **Applications:** Smart factories, predictive maintenance systems, micro-electromechanical systems (MEMS).		

TEXT BOOKS:

- Jain, V.K. – *Advanced Machining Processes* – Allied Publishers.
- McGeough, J.A. – *Advanced Methods of Machining* – Springer.
- Shaw, M.C. – *Metal Cutting Principles* (2nd ed.) – Oxford University Press.
- Davim, J.P. (Ed.) – *Machining of Hard Materials* – Springer.

REFERENCE BOOKS:

- Choudhury, S.K., and El-Baradie, M.A. – *Machining of Stainless Steels and Super Alloys* – Wiley.
- Byrne, G., Dornfeld, D., and Denkena, B. – *Advanced Cutting Processes* – CIRP Encyclopedia.
- López de Lacalle, L.N., and Lamikiz, A. – *Machine Tools for High Performance Machining* – Springer.
- Pandey, P.C., and Shah, H.S. – *Modern Machining Processes* – McGraw-Hill.
- ASM Handbook, Vol. 16: Machining – ASM International.

ONLINE RESOURCES:

- Coursera: *"Digital Manufacturing & Design Technology"* (University at Buffalo), *"Machining"* (Google).
- edX: *"MITx: Principles of Manufacturing"*.
- NPTEL (India): *"Advanced Machining Processes"* (IIT Kanpur), *"Precision Engineering"* (IIT Madras).

PRACTICAL LIST:

1. DOE & Optimization of Conventional Machining (Module 1 & 3):
   - *Task:* Conduct a milling or turning experiment (or use a provided dataset) on a difficult-to-machine material (e.g., Ti-6Al-4V or Inconel). Use Design of Experiments (DOE - Taguchi/RSM) to study the effect of speed, feed, depth of cut on surface roughness and cutting forces. Optimize for maximum material removal rate (MRR) with a surface finish constraint. Report with statistical analysis.
2. EDM Process Modeling & Micro-Hole Drilling Simulation (Module 2):
   - *Task:* Model a single spark in Electro-Discharge Machining using a simplified thermal model (e.g., in MATLAB/Python) to predict material removal rate and crater geometry. Then, use this to simulate a micro-EDM drilling process for a matrix of holes. Compare with experimental data from literature.
3. Hybrid Machining Analysis & Sustainability Assessment (Module 3):
   - *Task:* Select a component (e.g., a turbine blade). Compare two manufacturing routes: (a) Conventional milling + EDM for features, and (b) Additive Manufacturing (SLM) + finish machining. Perform a comparative analysis on key metrics: energy consumption, lead time, material waste, and cost. Use standard databases and simplified models.
4. Digital Twin & Tool Condition Monitoring Project (Module 4):

- *Task:*
  1. Part A: Develop a simplified digital twin of a milling process in a simulation environment (e.g., using MATLAB Simulink or a dedicated software demo). The twin should predict cutting forces and tool wear based on input parameters.
  2. Part B: Analyze a provided dataset from a tool condition monitoring experiment (vibration/ acoustic emission signals). Build a basic machine learning classifier (using Python/ scikit-learn) to classify the tool state as 'sharp', 'worn', or 'failure'.

SUBJECT CODE: MTME302

SUBJECT NAME: LEAN MANUFACTURING

Course Objectives:

- To provide a systematic understanding of Lean philosophy, principles, and tools for manufacturing excellence.
- To develop skills in value stream mapping, process optimization, and waste reduction in production systems.
- To bridge traditional Lean with digital transformation in the context of Industry 4.0.
- To prepare students for roles in manufacturing engineering, operations management, and continuous improvement.

Course Outcomes: At the end of the course students shall be able to

CO1	Analyze manufacturing systems using Lean principles to identify and eliminate waste (Muda) across value streams.
CO2	Design and implement core Lean tools including 5S, VSM, TPM, SMED, and Kanban systems.
CO3	Apply statistical process control and Six Sigma methodologies to achieve process stability and capability.
CO4	Integrate Lean principles with Industry 4.0 technologies (IoT, AI, Digital Twins) for Smart Lean Manufacturing.

Unit	Content	Credit	Weightage
I	**Foundations of Lean & Value Stream Management** • **Topics:** ○ Evolution of Lean: From craft production to Toyota Production System (TPS), Lean vs. Agile vs. Six Sigma. ○ The Seven (+1) Wastes (Muda): TIMWOODS (Transport, Inventory, Motion, Waiting, Over-processing, Over-production, Defects, Skills). ○ Lean Principles: Value, Value Stream, Flow, Pull, Perfection. ○ Value Stream Mapping (VSM): Current state mapping, future state design, implementation planning. ○ **Takt Time** calculation and line balancing.	1	25%

	○ Introduction to **Gemba Walks** and visual management. • **Applications:** Process analysis in automotive assembly, electronics manufacturing, discrete parts production.		
II	**Core Lean Tools & Just-in-Time (JIT) Systems** • **Topics:** ○ Workplace Organization: **5S Methodology** (Sort, Set in order, Shine, Standardize, Sustain). ○ Quick Changeover: **SMED (Single-Minute Exchange of Die)** methodology. ○ Pull Systems: **Kanban** systems (production, withdrawal, signal Kanban), supermarket systems. ○ **Jidoka** (Autonomation): Poka-Yoke (mistake-proofing), Andon systems. ○ **Total Productive Maintenance (TPM):** OEE (Overall Equipment Effectiveness), the eight pillars of TPM. ○ Standardized Work: Work combination tables, standard operating procedures (SOPs). • **Applications:** High-mix low-volume production, machine shop optimization, packaging lines.	1	25%
III	**Quality & Statistical Foundations for Lean** • **Topics:** ○ Introduction to Six Sigma: DMAIC framework, role in Lean Six Sigma. ○ **Statistical Process Control (SPC):** Control charts (X-bar R, p, c charts), process capability (Cp, Cpk). ○ Root Cause Analysis: **5 Whys**, Fishbone (Ishikawa) diagrams. ○ Problem-Solving Frameworks: **PDCA (Plan-Do-Check-Act)** and **A3 Thinking**. ○ Design for Lean Manufacturing (DFLM): Simplification, modular design, design for assembly. ○ **Lean Metrics:** Cycle time, throughput, WIP, Lead time, First Pass Yield. • **Applications:** Quality improvement in casting/forging, reducing rework in assembly, supplier quality management.	1	25%
IV	**Lean 4.0 & Advanced Implementation Strategies** • **Topics:**	1	25%

	◦ **Lean 4.0:** Integration of IoT, Big Data, and AI with Lean tools (e.g., digital Kanban, predictive maintenance). ◦ **Value Stream Management 4.0:** Digital VSM tools (e.g., iObeya, Lucidchart). ◦ **Lean in Service & Administrative Processes:** Lean office, transactional Lean. ◦ **Lean Culture & Leadership:** Hoshin Kanri (policy deployment), Kata (improvement routines), Lean transformation models. ◦ **Lean Supply Chain:** JIT delivery, Lean supplier development. ◦ **Sustainability through Lean:** Green Lean, energy and resource waste reduction. ◦ Case studies: Lean implementation in automotive (Toyota), aerospace (Boeing), and electronics (Dell). • **Applications:** Digital factory design, multi-plant Lean deployment, sustainable manufacturing initiatives.		

TEXT BOOKS:

- Womack, J.P., and Jones, D.T. – *Lean Thinking: Banish Waste and Create Wealth in Your Corporation* (2nd ed.) – Free Press.
- Rother, M., and Shook, J. – *Learning to See: Value Stream Mapping to Add Value and Eliminate Muda* – Lean Enterprise Institute.
- Liker, J.K. – *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer* – McGraw-Hill.
- George, M.L. – *Lean Six Sigma for Service* – McGraw-Hill.

REFERENCE BOOKS:

- Ohno, T. – *Toyota Production System: Beyond Large-Scale Production* – Productivity Press.
- Shingo, S. – *A Study of the Toyota Production System* – Productivity Press.
- Bicheno, J., and Holweg, M. – *The Lean Toolbox* (6th ed.) – PICSIE Books.
- Monden, Y. – *Toyota Production System: An Integrated Approach to Just-In-Time* (4th ed.) – CRC Press.
- Wilson, L. – *How to Implement Lean Manufacturing* (2nd ed.) – McGraw-Hill.

ONLINE RESOURCES:

- Coursera: *"Lean Production"* (University of Michigan), *"Six Sigma and Lean"* (Amsterdam University).
- edX: *"Lean Six Sigma"* (TUMx), *"Implementing Lean"* (Purdue University).
- Udemy: Courses on Value Stream Mapping, Lean Six Sigma Green Belt.

PRACTICAL LIST:

1. Value Stream Mapping (VSM) Project (Module 1):
   - *Task:* Select a real or simulated product family (e.g., bicycle assembly, pump manufacturing). Conduct a Current State VSM by mapping information and

material flow from customer order to delivery. Identify major wastes and calculate key metrics (Process Cycle Efficiency, Lead Time). Develop a Future State VSM with specific improvement proposals (e.g., implementing a supermarket, reducing batch sizes).

2. 5S & Workplace Organization Simulation (Module 2):
    - *Task:* In a lab setting (or using a virtual simulation tool), perform a 5S project on a designated "messy" workstation (e.g., a benchtop with tools, materials, and documents). Document each step with before/after photos. Create standardized work instructions and a 5S audit checklist. Present the impact on search time and potential error reduction.
3. SMED & Process Capability Study (Module 2 & 3):
    - *Task:* Analyze a changeover process (data provided for a machine setup, e.g., injection molding die change or CNC tooling change). Apply SMED methodology to separate internal and external activities, convert internal to external, and streamline operations. Also, collect data on a critical dimension from a process (provided dataset) and perform a Process Capability Analysis (construct control charts, calculate Cp/Cpk). Propose corrective actions if the process is not capable.
4. Lean 4.0 Digital Transformation Proposal (Module 4):
    - *Task:* Choose a traditional Lean tool (e.g., manual Kanban, paper-based Andon, preventive maintenance logs). Design a digital/ Industry 4.0 enhanced version of this tool. For example:
        1. Design an IoT-enabled Andon system using a conceptual architecture (sensors, cloud dashboard, mobile alerts).