DAYANANDA SAGAR UNIVERSITY

SCHOOL OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

Devarakaggalahalli, Harohalli Kanakapura Road, Dt, Ramanagara, Karnataka 562112

SCHEME & SYLLABUS

MASTER OF TECHNOLOGY (M.Tech)

SPECIALIZATION: DESIGN ENGINEERING

(2026 – 2028 Batch)

Dayananda Sagar University
School of Engineering
Department of Mechanical Engineering
Devarakaggalahalli, Harohalli Kanakapura Road, Dt, Ramanagara, Karnataka 562112

Definitions / Descriptions

Definition of Credit:	
1 Hour Lecture (L) Per Week	01 Credit
1 Hour Tutorial (T) Per Week	01 Credit
1 Hour Practical (P) Per Week	0.5 Credit
1 Hour Project (J) Per Week	0.5 Credit

Course code and Definition:	
BSC	Basic Science Courses
ESC	Engineering Science Courses
HSMC	Humanities and Social Sciences including Management Courses
IPCC	Integrated Professional Core Course
PCC	Professional Core Courses
PEC	Professional Elective Courses
OEC	Open Elective Courses
SEC	Skill Enhancement Courses
UHV	Universal Human Value Course
PROJ	Project Work
INT	Internship

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SCHEME 2026 – 2027 Batch

I SEMESTER													
Sl. No.	Course Type	Course Code	Course Name	Teaching Department	Teaching Hours / Week				Examination				Credits
					Lecture	Tutorial	Practical	Project	Duration in Hrs.	CIE Marks	SEE Marks	Total Marks	
					L	T	P	J					
1	BSC	26MDE5101	Computational Numerical Methods, Statistics and Optimization	Mech	3	0	0	0	03	60	40	100	**03**
2	IPCC	26MDE5102	Applied Finite Element Methods	Mech	3	0	2	0	05	60	40	100	**04**
3	IPCC	26MDE5103	Advanced Solid Mechanics for Design Applications	Mech	3	0	2	0	05	60	40	100	**04**
4	PCC	26MDE5104	Artificial Intelligence for Mechanical System Design	Mech	3	0	0	0	03	60	40	100	**03**
5	PEC	26MDE51XX	Professional Elective – I	Mech	3	0	0	0	03	60	40	100	**03**
6	PEC	26MDE51XX	Professional Elective – II	Mech	3	0	0	0	03	60	40	100	**03**
7	SEC	26MDE51XX	Skill Enhancement Course-I	Mech	0	0	4	0	04	100	-	100	**02**
			Total		**18**	**0**	**8**	**0**	**26**	**460**	**240**	**700**	**22**

Skill Enhancement Course – I					
SEC	26MDE5115	Python Programming for Design Engineers	SEC	26MDE5117	Digital Product Design using Autodesk Inventor/Fusion 360
SEC	26MDE5116	Engineering Simulation using ANSA	SEC	26MDE5118	Accelerating Computer-Aided Engineering (CAE) with NVIDIA AI Physics Technology

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SCHEME 2026 – 2027 Batch

II SEMESTER													
Sl. No.	Course Type	Course Code	Course Name	Teaching Department	Teaching Hours /Week				Examination				Credits
					Lecture	Tutorial	Practical	Project	Duration in Hrs.	CIE Marks	SEE	Total Marks	
					L	T	P	J					
1	IPCC	26MDE5201	Modern Materials and Manufacturing Technology	Mech	3	0	2	0	05	60	40	100	**04**
2	IPCC	26MDE5202	Advanced Composite Materials for Design	Mech	3	0	2	0	05	60	40	100	**04**
3	PCC	26MDE5203	Generative AI for Mechanical Design	Mech	3	0	0	0	03	60	40	100	**03**
4	PCC	26MDE5204	Mechatronic System Design	Mech	3	0	0	0	03	60	40	100	**03**
5	PEC	26MDE52XX	Professional Elective – III	Mech	3	0	0	0	03	60	40	100	**03**
6	PEC	26MDE52XX	Professional Elective – IV	Mech	3	0	0	0	03	60	40	100	**03**
7	SEC	26MDE52XX	Skill Enhancement Course-II	Mech	0	0	4	0	04	100	-	100	**02**
			Total		**18**	**0**	**08**	**0**	**26**	**460**	**240**	**700**	**22**

Skill Enhancement Course – II					
SEC	26MDE5215	Industrial Hydraulic and Pneumatic Systems	SEC	26MDE5217	AI and Deep Learning for Design Engineers
SEC	26MDE5216	Computational Engineering using MATLAB	SEC	26MDE5218	Engineering Makerspace and Product Prototyping

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SCHEME 2026 – 2027 Batch

III SEMESTER

Sl. No.	Course Type	Course Code	Course Name	Teaching Department	Teaching Hours / Week				Examination				Credits
					Lecture	Tutorial	Practical	Project	Duration in Hrs.	CIE Marks	SEE Marks	Total Marks	
					L	T	P	J					
1	PROJ	26MDE5301	Dissertation Phase - I	Mech	0	0	0	12	12	100	-	100	**06**
2	INT	26MDE5302	Internship	Mech	0	0	0	12	12	100	-	100	**06**
3	PEC	26MDE53XX	Professional Elective – V	Mech	03	0	0	0	03	60	40	100	**03**
			Total		**03**	**0**	**0**	**24**	**27**	**260**	**40**	**300**	**15**

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SCHEME 2026 – 2027 Batch

IV SEMESTER

Sl. No.	Course Type	Course Code	Course Name	Teaching Department	Teaching Hours / Week				Examination				Credits
					Lecture	Tutorial	Practical	Project	Duration in Hrs.	CIE Marks	SEE Marks	Total Marks	
					L	T	P	J					
1	PROJ	26MDE5401	Dissertation Phase - II	Mech	0	0	0	24	24	60	40	100	**12**
2	PEC	26MDE54XX	Professional Elective – VI	Mech	03	0	0	0	03	60	40	100	**03**
			Total		**03**	**0**	**0**	**24**	**27**	**120**	**80**	**200**	**15**

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PROFESSIONAL ELECTIVES

PROFESSIONAL ELECTIVES – I			PROFESSIONAL ELECTIVES – II		
SL. No.	COURSE CODE	COURSE TITLE	SL. No.	COURSE CODE	COURSETITLE
1	26MDE5105	Automotive Electronics and Embedded Control Systems	1	26MDE5110	Smart Sensors and Industrial Instrumentation Systems
2	26MDE5106	Product Design and Development Methodologies	2	26MDE5111	Hydraulic and Pneumatic System Engineering
3	26MDE5107	Industrial Design, Ergonomics and Human-Centered Engineering	3	26MDE5112	Lean Manufacturing and Smart Production Systems
4	26MDE5108	Advanced Vibro-Acoustic Engineering	4	26MDE5113	Smart Materials and Adaptive Structural Systems
5	26MDE5109	Reliability Engineering and Failure Diagnostics	5	26MDE5114	AI-Driven Structural Analysis and Mechanics

PROFESSIONAL ELECTIVES – III			PROFESSIONAL ELECTIVES – IV		
SL. No.	COURSE CODE	COURSE TITLE	SL. No.	COURSE CODE	COURSETITLE
1	26MDE5205	Product Lifecycle Engineering in Industry 4.0	1	26MDE5210	Digital Twin Technologies for Smart Industrial Systems
2	26MDE5206	Computational Engineering Modeling and Simulation	2	26MDE5211	Embedded Systems for Intelligent Mechanical Applications
3	26MDE5207	Data-Driven Design Optimization Techniques	3	26MDE5212	Advanced Machine Design
4	26MDE5208	Parallel and High-Performance Computing for Engineering	4	26MDE5213	Micro and Nano Electro-Mechanical Systems (MEMS/NEMS)
5	26MDE5209	Additive and Hybrid Manufacturing Systems	5	26MDE5214	Non-Destructive Testing and Structural Health Evaluation

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SCHEME 2026 – 2027 Batch

PROFESSIONAL ELECTIVES – V			PROFESSIONAL ELECTIVES – VI		
SL. No.	**COURSE CODE**	**COURSE TITLE**	**SL. No.**	**COURSE CODE**	**COURSE TITLE**
1	26MDE5303	Advanced Automotive Control and Mobility Systems	1	26MDE5402	Machine Learning for Intelligent Engineering Systems
2	26MDE5304	Robotics Simulation and Digital Prototyping	2	26MDE5403	Finite Element Applications in Structural Engineering
3	26MDE5305	Engineering Optimization and Decision-Making Techniques	3	26MDE5404	Material Handling and Industrial System Automation
4	26MDE5306	Applied Engineering Statistics and Process Optimization	4	26MDE5405	Computational Fracture and Damage Mechanics
5	26MDE5307	Structural Reliability and Failure Prevention Engineering	5	26MDE5406	Industry 4.0 and Smart Manufacturing Integration

Computational Numerical Methods, Statistics and Optimization

(As per Choice Based Credit System)	
Course Code: 26MDE5101	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mathematics, Numerical Methods, Probability and Statistics	
Course Type: BSC	**Hours/Week:** 03 **Total Hours:** 45 Hrs. **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop advanced analytical and computational skills in numerical methods, optimization, probability, statistics, and engineering data analysis for solving complex design and engineering problems.

Course Objectives

Students will be able to:

- Understand advanced numerical and statistical methods used in engineering analysis and optimization.
- Apply interpolation, regression, and curve-fitting techniques for engineering data modeling.
- Analyze engineering systems using probability, statistical analysis, and design of experiments.
- Solve partial differential equations using numerical computational techniques.
- Apply numerical linear algebra methods for engineering and finite element applications.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the concepts of calculus of variations and constrained and unconstrained optimization used in engineering design problems.	L2
CO2	Apply interpolation, regression, and curve-fitting techniques to model experimental and engineering data.	L3

CO	Course Outcome	BTL
CO3	Analyze engineering data and quality problems using probability distributions, hypothesis testing, correlation, and design of experiments.	L4
CO4	Solve engineering problems governed by partial differential equations using explicit, implicit, and Crank–Nicolson numerical methods.	L3
CO5	Apply direct and iterative numerical linear algebra techniques to computational and finite element engineering problems.	L3

Broad Course Description

This course introduces advanced numerical methods and statistical techniques widely used in engineering design, computational mechanics, optimization, and engineering data analysis. The course emphasizes mathematical modeling, numerical computation, probabilistic analysis, and engineering applications.

Learners will gain exposure to:

- Calculus of variations and optimization
- Curve fitting and interpolation methods
- Probability and statistical analysis
- Design of experiments (DOE)

Detailed Course Syllabus

Course Modules

Module 1: Calculus of Variations and Engineering Optimization (9 Hours)

Introduction to Calculus of Variations, First Variation, Euler–Lagrange Equation, Isoperimetric Problems, Constrained and Unconstrained Optimization, Engineering Design Optimization Applications.

Engineering Applications: Structural optimization, minimum weight design, thermal system optimization, machine design optimization.

Module 2: Curve Fitting and Interpolation Techniques (9 Hours)

Linear and Polynomial Regression, Least Squares Method, Newton's Divided Difference Interpolation, Lagrange Interpolation, Inverse Interpolation, Spline Interpolation, Multidimensional Interpolation, Engineering Case Studies.

Engineering Applications: Experimental data analysis, performance prediction, CAD/CAM curve generation, sensor data approximation.

Module 3: Probability, Statistics and Design Engineering Applications (9 Hours)

Probability Concepts, Random Variables and Distributions, Statistical Measures, Correlation and

Regression Analysis, Design of Experiments (DOE), Hypothesis Testing, Statistical Quality Control, Reliability and Engineering Data Analysis.

Engineering Applications: Reliability engineering, manufacturing quality control, experimental analysis, industrial process optimization.

Module 4: Numerical Solution of Partial Differential Equations (9 Hours)

Laplace Equation, Boundary Conditions, Control Volume Approach, Heat Conduction Equation, Explicit and Implicit Methods, Crank–Nicolson Method, Parabolic Equations in Two Spatial Domains, Engineering Applications and Case Studies.

Engineering Applications: Heat transfer analysis, fluid flow modeling, transient thermal systems, computational engineering simulations.

Module 5: Numerical Linear Algebra and Computational Methods (9 Hours)

Partition Method, Crout's Triangularization Method, Eigenvalues and Eigenvectors, Jacobi Method for Symmetric Matrices, Gauss Elimination, LU Decomposition, Gauss–Seidel Method, Applications in Finite Element and Design Engineering Problems.

Engineering Applications: Finite element analysis, structural mechanics, vibration analysis, computational mechanics.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	1	2	–	3	–	–	–	–	–	–	1	2
CO2	2	3	–	2	1	–	–	–	–	–	–	–	–
CO3	2	3	2	2	1	–	–	–	–	–	–	2	3
CO4	2	1	1	–	2	–	–	–	–	–	–	–	2
CO5	1	1	1	–	3	–	–	–	–	–	–	–	2

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Understand AI-assisted numerical computation and statistical analysis techniques for engineering modeling and optimization.

Example: Analyze engineering experimental data for predictive modeling:

- Collect engineering experimental data.
- Perform regression and interpolation analysis.
- Apply statistical quality analysis methods.
- Solve computational engineering problems numerically.
- Use AI-assisted tools for prediction and optimization.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Suggested Reading

Primary Textbooks

- M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International.
- Steven C. Chapra and Raymond P. Canale, Numerical Methods for Engineers, McGraw Hill.

Reference Books

- Gerald and Wheatley, Applied Numerical Analysis, Pearson Education.
- Douglas C. Montgomery and George C. Runger, Applied Statistics and Probability for Engineers, Wiley.
- B. S. Grewal, Higher Engineering Mathematics, Khanna Publishers.
- Erwin Kreyszig, Advanced Engineering Mathematics, Wiley.

Additional Resources

- NPTEL – Numerical Methods and Computational Engineering
- MATLAB Documentation and Tutorials
- ANSYS Computational Learning Resources
- MIT OpenCourseWare – Numerical Analysis
- Engineering Statistics Learning Modules

DLI Course Mapped

Fundamentals of Accelerated Computing and Numerical Analysis
https://learn.nvidia.com/

DLI Learning Path

- AI-Assisted Computational Engineering
- Engineering Data Analytics
- Numerical Simulation and Optimization
- Intelligent Engineering Computation Systems

Applied Finite Element Methods

(As per Choice Based Credit System)	
Course Code: 26MDE5102	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mathematics, Mechanics of Solid, Numerical Methods	
Course Type: IPCC	**Hours/Week:** 05 **Total Hours:** 45 Hrs Theory + 30 Hrs Lab **Credits:** 04
L – T – P – J: 3-0-2-0	

Course Vision

This course develops the ability to formulate structural systems mathematically, construct finite element models, and interpret computational results for reliable analysis, design, and performance assessment of engineering structures.

Course Objectives

Students will be able to:

- Apply variational principles, weak formulation, and FE discretization concepts to structural systems.
- Derive element equations for truss, beam, frame, and continuum elements used in structural analysis.
- Assemble global FE equations, apply boundary conditions, and solve structural response problems.
- Evaluate mesh convergence, numerical error, and modeling assumptions for reliable FE prediction.
- Use FE software, scripting, and AI-assisted tools to validate models and interpret structural results.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain weighted residual, Rayleigh–Ritz, Galerkin, and variational principles and the role of shape functions in finite element	L2

CO	Course Outcome	BTL
	discretization.	
CO2	Apply the direct stiffness method to obtain stiffness matrices, equivalent nodal loads, and responses of truss, beam, and frame elements.	L3
CO3	Analyze two-dimensional plane stress, plane strain, and axisymmetric problems using CST, LST, and isoparametric elements with numerical integration.	L4
CO4	Assemble global finite element equations, apply constraints, and perform mesh-convergence studies to verify the accuracy of structural solutions.	L3
CO5	Analyze buckling, modal, and nonlinear structural behavior using FE software and interpret the results for design decisions.	L4
CO6	Conduct finite element experiments using MATLAB/Python and FE software, including modelling, scripting, and comparison with hand calculations, and report a structural mini-project.	L4

Broad Course Description

This course introduces the finite element method as a powerful numerical tool for structural modeling and analysis. It emphasizes the underlying mathematics, element formulation, assembly procedures, boundary treatment, and post-processing required to study real structural systems. Students will learn to convert complex continua and assemblies into solvable discrete models and to assess the engineering meaning of the predicted stresses, strains, displacements, and modes. The course is designed for postgraduate learners and blends theory with computational practice. Along with conventional finite element concepts, the course introduces modeling decisions that affect solution fidelity, such as element type selection, aspect ratio, convergence study, nonlinear response, dynamic effects, and verification against closed-form or benchmark solutions.

Detailed Course Syllabus

Course Modules

Module 1: Variational Foundations and FE Discretization (9 Hours)

Introduction to engineering approximation, review of structural idealization, weighted residual methods, Rayleigh-Ritz method, Galerkin method, weak form of governing equations, concepts of interpolation, shape functions, compatibility, completeness, and convergence requirements. One-dimensional bar and axial member formulation, element equations, boundary conditions, and post-

processing.

Engineering Applications: axial load members, hangers, tie rods, suspension components

Module 2: Beam, Truss, and Frame Elements (9 Hours)

Direct stiffness formulation for truss and frame members, beam bending elements, Hermite interpolation, local and global coordinate systems, transformation matrices, equivalent nodal loads, consistent load vectors, and support conditions. Assembly of member matrices into a structural system and interpretation of internal force output.

Engineering Applications: building frames, crane booms, machine supports, bridge secondary members

Module 3: 2D Continuum Elements and Structural Idealization (9 Hours)

Two-dimensional stress and strain problems, CST and LST elements, isoparametric formulation, numerical integration, stress recovery, plane stress, plane strain, axisymmetric idealization, and introduction to plate and shell concepts. Selection of element order and assessment of stress concentration zones.

Engineering Applications: plates with openings, brackets, slab zones, axisymmetric pressure vessels

Module 4: Global Assembly, Solution Strategy, and Convergence (9 Hours)

Assembly of global stiffness matrices, application of constraints, handling multi-point constraints, static condensation, solution of linear systems, sparsity concepts, conditioning, convergence study, error estimation, and mesh refinement strategies. Verification through benchmark problems and comparison with analytical solutions.

Engineering Applications: large structural assemblies, substructure condensation, verification of design models

Module 5: Advanced Structural FE Analysis and Applications (9 Hours)

Introduction to nonlinear material behavior, geometric nonlinearity, contact basics, modal analysis, buckling, transient response, thermal-stress coupling, and design interpretation. Overview of structural software workflows, result validation, documentation, and engineering judgment in model-based decision making.

Engineering Applications: buckling of columns and frames, vibration serviceability, thermal distortion, performance assessment

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	–	3	–	1	–	1	–	–	–	–	–	2
CO2	2	–	–	–	1	–	–	–	–	–	–	–	2
CO3	2	1	–	–	1	–	–	–	–	–	–	–	2
CO4	2	3	–	–	3	–	–	–	–	–	–	–	3
CO5	2	3	–	2	3	–	–	–	–	–	–	–	2

CO6	2	2	–	3	3	–	–	–	–	–	–	–	3

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

Aim: Understand how structural response can be learned from simulation data and how AI complements finite element analysis in modern structural engineering practice.

- Generate a small training set from FE simulations and fit a regression model to predict displacement or stress.
- Use vibration response data to classify damage states or support conditions.
- Compare FE outputs with AI predictions and discuss error, robustness, and interpretability.
- Build a simple digital-twin style workflow in which sensor inputs update a structural response model.

Laboratory / Practical Component

The following activities may be carried out using MATLAB / Python, Abaqus, ANSYS, CalculiX, or equivalent FE software:

Lab Experiments

- Develop a bar element model and verify nodal displacements for a stepped axial member.
- Create a truss model for a planar roof or bridge truss and compare reactions with hand calculations.
- Model a beam and frame system, extract deflections, shear force, bending moment, and reactions.
- Perform a mesh convergence study for a plate or continuum element problem.
- Compare plane stress and plane strain responses for a structural component.
- Study Eigen frequencies of a frame or beam model and interpret modal shapes.
- Investigate buckling load variation with slenderness ratio for a column.
- Simulate a nonlinear material response or contact condition for a structural example.
- Use scripting to automate model creation, post-processing, and report generation.
- Prepare one mini-project on a practical structural system such as a bracket, frame joint, or slab panel.

AI-Integrated Lab Exercise (Indicative)

- Use a lightweight regression model to predict displacement or stress from a small set of design variables and compare the prediction with FE output.
- Develop a data-driven post-processing workflow for automated interpretation of structural response trends.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises three Continuous Assessment Tests (CAT–1, CAT–2, CAT–3) aligned with course modules and Bloom's Taxonomy levels, one Mid-Semester Examination (MSE), and one Continuous Assessment component, as detailed in the table below.

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 20	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Continuous Laboratory Assessment	Lab Integrated Component – Experiments / Practical Activities	CO6 (L2–L5)	10	Continuous evaluation of practical skills, experimental procedure, application of concepts, data collection and analysis, interpretation of results, troubleshooting and technical documentation. Lab Performance / Experiment Execution / Lab Record / Practical Assignment / Simulation or CAD Activity / Mini Project / Problem-Based Practical Activity
Total CIA	Modules 1–5		60	
SEE	Comprehensive Syllabus	As applicable	40	End-Semester Examination
Grand Total			**100**	

Recommended Tools

- FE and structural software: ANSYS, Abaqus, ETABS, STAAD.Pro, OpenSees, or equivalent.

- Programming and analytics: Python, MATLAB, and spreadsheet-based verification.
- AI tools: scikit-learn, basic deep learning libraries, and cloud notebook environments.

Suggested Reading

Primary Textbooks

- K. J. Bathe, Finite Element Procedures, Prentice Hall.
- T. R. Chandrupatla and A. D. Belegundu, Introduction to Finite Elements in Engineering, Pearson.

Reference Books

- S. S. Bhavikatti, Finite Element Analysis, New Age International.
- O. C. Zienkiewicz, R. L. Taylor and J. Z. Zhu, The Finite Element Method: Its Basis and Fundamentals, Elsevier.
- C. S. Krishnamoorthy, Finite Element Analysis: Theory and Programming, Tata McGraw-Hill.

Additional Resources

- NPTEL modules on structural finite element analysis.
- Vendor manuals and benchmark examples from structural FE software packages.

DLI Course Mapped

Fundamentals of Accelerated Computing with CUDA C/C++
https://learn.nvidia.com/

DLI Learning Path

- Accelerated Computing for Finite Element Analysis
- AI-Assisted Mesh Generation and Simulation
- GPU-Accelerated Structural Solvers

Advanced Solid Mechanics for Design Applications

(As per Choice Based Credit System)	
Course Code: 26MDE5103	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mechanics, Mechanics of Materials, Strength of Materials, Machine Design	
Course Type: IPCC	**Hours/Week:** 05 **Total Hours:** 45 Hrs Theory + 30 Hrs Lab **Credits:** 04
L – T – P – J: 3 – 0 – 2 – 0	

Course Vision

This course aims to develop advanced understanding of stress, strain, deformation, failure, and energy-based methods used in mechanical design. It enables students to analyze complex engineering components subjected to combined loading, stress concentration, torsion, bending, shear, buckling, contact, and fatigue conditions. The course emphasizes application-oriented solid mechanics for safe, reliable, and optimized design of machine members, structural components, automotive systems, aerospace structures, pressure vessels, shafts, beams, plates, and joints. Students will also gain exposure to computational tools, simulation-based validation, and AI-assisted interpretation of stress and deformation results.

Course Objectives

Students will be able to:

- Gain knowledge of advanced stress–strain relations, principal stresses, strain energy, and theories of failure for design applications.
- Analyze beams, shafts, cylinders, pressure vessels, and structural members subjected to complex loading conditions.
- Apply energy methods and stability concepts to solve deformation, buckling, and impact loading problems.
- Evaluate stress concentration, fatigue failure, fracture, and contact stresses in engineering components.
- Make use of analytical, computational, and AI-assisted tools to interpret solid mechanics problems for design decision-making.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain stress–strain transformation, principal stresses, Mohr's circle, and failure theories used in mechanical design.	L2
CO2	Apply theories of bending, torsion, shear, and combined loading to determine stresses in beams, shafts, curved members, and pressure components.	L3
CO3	Apply strain energy methods, Castigliano's theorem, and impact loading concepts to determine deformation and load response of members.	L3
CO4	Apply buckling, stress-concentration, fatigue, fracture, and contact-stress criteria to estimate the load capacity and safety factors of engineering components.	L3
CO5	Analyze analytical and simulation-based solid mechanics results to support safe, optimized, and reliable component design.	L4
CO6	Analyze design-oriented problems in the tutorial/practice sessions using spreadsheet, MATLAB/Python, and FEA tools, and compare analytical results with simulation results for a component.	L4

Broad Course Description

This course provides an advanced treatment of solid mechanics with emphasis on engineering design applications. It builds upon fundamental mechanics of materials and introduces advanced concepts such as three-dimensional stress and strain, generalized Hooke's law, failure theories, strain energy, curved beams, thick cylinders, torsion of non-circular sections, stress concentration, fatigue, fracture mechanics, buckling, and contact stresses. The course connects analytical methods with practical design problems and introduces simulation-based interpretation using finite element analysis tools. Students will solve real-world design cases involving shafts, brackets, pressure vessels, springs, beams, columns, joints, gears, and load-bearing structures.

Detailed Course Syllabus

Course Modules

Module 1: Advanced Stress–Strain Analysis and Failure Theories (9 Hours)

Concept of stress at a point, state of stress in two and three dimensions, stress tensor, strain tensor, generalized Hooke's law, plane stress and plane strain conditions, principal stresses and principal strains, Mohr's circle for stress and strain, octahedral stresses, strain rosette analysis, theories of failure: maximum principal stress theory, maximum shear stress theory, maximum strain energy

theory, distortion energy theory, Coulomb–Mohr theory, comparison of failure theories for ductile and brittle materials.

Engineering Applications: Design evaluation of brackets, crane hooks, machine frames, pressure joints, automotive suspension components, and load-bearing mechanical members under multiaxial stress conditions.

Module 2: Bending, Torsion, Shear and Combined Loading in Design (9 Hours)

Unsymmetrical bending, shear center, bending of curved beams, stresses in hooks and rings, torsion of circular and non-circular shafts, thin-walled tubular sections, combined bending and torsion, eccentric loading, shear flow in built-up sections, design of shafts under fluctuating and combined loads, thick and thin pressure vessels, Lame's equations for thick cylinders, compound cylinders, rotating discs and cylinders.

Engineering Applications: Design of transmission shafts, pressure vessels, flywheels, hooks, curved machine members, thin-walled structures, tubular frames, and mechanical power transmission components.

Module 3: Energy Methods and Deformation Analysis (9 Hours)

Strain energy due to axial load, bending, torsion, and shear; resilience and proof resilience; Castigliano's first and second theorem; Maxwell–Betti reciprocal theorem; unit load method; deflection of beams, frames, rings, and curved members; impact loading; suddenly applied loads; thermal stresses; residual stresses; introduction to elastic stability and energy-based design checks.

Engineering Applications: Deflection analysis of machine frames, spring systems, aircraft and automotive brackets, crane structures, beams, support frames, and components subjected to shock or impact loading.

Module 4: Buckling, Fatigue, Fracture and Contact Mechanics (9 Hours)

Euler buckling of columns, effective length and end conditions, and Johnson's parabolic formula for intermediate columns; stress concentration factors and notch sensitivity. Fatigue design: S–N curve, endurance limit, mean-stress criteria (Goodman, Gerber, Soderberg), and cumulative damage by Miner's rule. Basics of fracture mechanics: stress intensity factor and fracture toughness. Hertz contact stresses.

Engineering Applications: Design of columns, connecting rods, suspension arms, gears, bearings, shafts with keyways, bolted joints, welded joints, springs, rolling contact elements, and components subjected to repeated or impact loading.

Module 5: Solid Mechanics for Simulation-Based Design and Optimization (9 Hours)

Introduction to finite element interpretation in solid mechanics, idealization of geometry, boundary conditions, meshing considerations, material models, linear static analysis, stress singularities, convergence, interpretation of von Mises stress, principal stress, displacement, factor of safety and strain energy results, validation of simulation using analytical calculations, design optimization based on stress reduction, stiffness improvement, weight reduction and fatigue life enhancement, introduction to AI-assisted design review and result interpretation.

Engineering Applications: FEA-based design review of brackets, shafts, plates, frames, pressure components, mechanical joints, automotive parts, aerospace structures, and lightweight components.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	1	3	–	2	–	–	–	–	–	–	1	3
CO2	2	3	–	–	1	–	–	–	–	–	–	–	–
CO3	3	2	–	–	2	–	1	–	–	–	–	–	3
CO4	2	3	–	–	1	–	–	–	–	–	–	–	3
CO5	2	3	3	–	3	–	–	–	–	–	–	2	3
CO6	2	3	2	2	3	–	–	–	–	–	–	1	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Understand how Artificial Intelligence and computational tools can accelerate stress analysis, failure prediction, and design optimization in solid mechanics problems.

Example Activities:

- Use AI/ML tools to predict stress concentration factors for complex geometries and compare with analytical solutions.
- Develop a machine-learning model to classify failure modes from simulated stress-strain data.
- Apply AI-assisted mesh refinement strategies to improve FEA convergence near stress singularities.
- Simulate AI-assisted fatigue life prediction using S-N curve datasets.
- Compare conventional analytical solutions and AI-assisted surrogate models for beam and shaft deflection prediction.

Laboratory / Practical Component

The tutorial component emphasizes problem-solving and design interpretation. Students will solve analytical problems and validate selected cases using spreadsheet tools, MATLAB, Python, or FEA software.

Tutorial / Design Practice Exercises

- Determine principal stresses, principal strains, and maximum shear stress for a given plane stress condition.
- Construct Mohr's circle and identify the critical plane orientation.
- Compare Tresca and von Mises failure criteria for a ductile machine component.
- Analyze a shaft subjected to combined bending and torsion and determine the required diameter.

- Calculate stresses in a curved beam such as crane hook or C-clamp.
- Analyze stresses in a thick cylinder subjected to internal pressure.
- Determine deflection of a beam using Castigliano's theorem.
- Analyze impact loading on a mechanical member and estimate maximum stress.
- Evaluate column buckling load for different end conditions.
- Estimate fatigue factor of safety using Goodman, Soderberg, and Gerber criteria.
- Determine stress concentration effect for a shaft with shoulder fillet or keyway.
- Analyze Hertz contact stress in gear tooth, bearing, or roller contact.
- Perform a simple FEA study of a bracket and compare analytical and simulation results.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises three Continuous Assessment Tests (CAT–1, CAT–2, CAT–3) aligned with course modules and Bloom's Taxonomy levels, one Mid-Semester Examination (MSE), and one Continuous Assessment component, as detailed in the table below.

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 20	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Continuous Laboratory Assessment	Lab Integrated Component – Experiments / Practical Activities	CO6 (L2–L5)	10	Continuous evaluation of practical skills, experimental procedure, application of concepts, data collection and analysis, interpretation of results, troubleshooting and technical documentation. Lab Performance / Experiment Execution / Lab

				Record / Practical Assignment / Simulation or CAD Activity / Mini Project / Problem-Based Practical Activity
Total CIA	Modules 1–5		60	
SEE	Comprehensive Syllabus	As applicable	40	End-Semester Examination
Grand Total			**100**	

Recommended Tools

- Analytical Calculation: Scientific calculator, spreadsheet tools
- Programming / Computation: MATLAB / Python / GNU Octave
- Simulation Tools: ANSYS / Abaqus / Fusion 360 Simulation / SolidWorks Simulation / FreeCAD FEM
- Design Documentation: MS Word / LaTeX / Google Docs
- AI-Assisted Learning Tools: ChatGPT, GitHub Copilot, WolframAlpha, engineering calculation verification tools

Suggested Reading

Primary Textbooks

- S. P. Timoshenko and J. N. Goodier, Theory of Elasticity, McGraw Hill.
- Richard G. Budynas and J. Keith Nisbett, Shigley's Mechanical Engineering Design, McGraw Hill.
- S. S. Rattan, Strength of Materials, McGraw Hill.

Reference Books

- L. S. Srinath, Advanced Mechanics of Solids, Tata McGraw Hill.
- Arthur P. Boresi and Richard J. Schmidt, Advanced Mechanics of Materials, Wiley.
- James M. Gere and Barry J. Goodno, Mechanics of Materials, Cengage Learning.
- Robert L. Norton, Machine Design: An Integrated Approach, Pearson.
- Ugural and Fenster, Advanced Strength and Applied Elasticity, Pearson.

Additional Resources

- NPTEL – Advanced Solid Mechanics
- NPTEL – Strength of Materials
- NPTEL – Design of Machine Elements
- MIT OpenCourseWare – Solid Mechanics
- ANSYS Innovation Courses – Structural Mechanics

DLI Course Mapped

Fundamentals of Accelerated Computing https://learn.nvidia.com/

DLI Learning Path

- Accelerated Computing
- Physics-Informed Machine Learning
- AI-Assisted Stress and Failure Analysis

Artificial Intelligence for Mechanical System Design

(As per Choice Based Credit System)	
Course Code: 26MDE5104	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Fundamentals of Mechanical Engineering, Engineering Mathematics, Basic Programming Knowledge	
Course Type: PCC	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course develops the ability to integrate artificial intelligence techniques with mechanical system design for intelligent engineering applications. The learners gain knowledge in machine learning, neural networks, optimization, data-driven modeling, and intelligent decision-making techniques for advanced mechanical systems. The course also enables students to implement AI-based predictive and generative approaches for engineering design, simulation, monitoring, and smart manufacturing applications.

Course Objectives

Students will be able to:

- Understand the fundamentals of artificial intelligence and machine learning techniques applicable to mechanical engineering systems.
- Explore data-driven approaches for modeling, prediction, and optimization in mechanical system design.
- Demonstrate the use of neural networks and deep learning techniques for intelligent engineering analysis.
- Apply AI algorithms for predictive maintenance, structural monitoring, and manufacturing process optimization.
- Introduce generative AI and intelligent automation concepts for modern mechanical system design applications.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the fundamental concepts of artificial intelligence, machine learning, and data preprocessing techniques for engineering problem solving.	L2
CO2	Apply supervised and unsupervised learning algorithms to analyze engineering datasets for mechanical system applications.	L3
CO3	Develop predictive models using neural networks and deep learning techniques for mechanical design and performance evaluation.	L4
CO4	Develop AI-based solutions for predictive maintenance, intelligent manufacturing, and structural health monitoring applications.	L3
CO5	Implement generative AI and optimization techniques for smart mechanical system design and intelligent engineering automation.	L3

Broad Course Description

This course introduces students to the concepts and applications of artificial intelligence in mechanical system design and intelligent engineering analysis. It focuses on integrating AI methodologies with mechanical engineering principles to solve real-world industrial challenges.

Learners will gain hands-on experience in engineering data analysis, machine learning model development, predictive analytics, neural networks, optimization algorithms, and AI-assisted design methodologies. The course also emphasizes intelligent automation, smart manufacturing systems, digital engineering practices, and data-driven decision-making for mechanical applications.

Beyond conventional AI methods, the course introduces deep learning and generative AI techniques for advanced engineering design applications. The course includes topics namely, AI fundamentals and machine learning concepts, Engineering data preprocessing and feature extraction, Regression and classification techniques, Artificial neural networks and deep learning, Predictive maintenance and intelligent monitoring, AI-driven optimization and generative design approaches.

Through a blend of theoretical concepts and practical implementation, the course nurtures the capability to develop intelligent engineering systems for modern industrial applications.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Artificial Intelligence for Mechanical Systems (9 Hours)

Introduction to Artificial Intelligence and Intelligent Systems: History and evolution of AI, AI in engineering applications, Intelligent mechanical systems, Types of AI, AI workflow for engineering design. Fundamentals of Machine Learning: Supervised learning, unsupervised learning, reinforcement learning concepts, Engineering datasets, Data acquisition methods, Data

preprocessing, Feature extraction and normalization. Introduction to Python libraries for AI: NumPy, Pandas, Matplotlib and Scikit-learn overview.

Engineering Applications: Smart manufacturing systems, Intelligent robotic assembly systems

Module 2: Machine Learning Techniques for Mechanical Design (9 Hours)

Regression and Classification Techniques: Linear regression, Polynomial regression, Logistic regression, Decision trees, Random forests, Support Vector Machines, K-Nearest Neighbour algorithm. Clustering and dimensionality reduction techniques: K-means clustering, Principal Component Analysis (PCA). Model evaluation methods: Training and testing datasets, Confusion matrix, Accuracy, Precision, Recall, F1-score and Cross-validation.

Engineering Applications: Tool wear prediction, Failure diagnosis in rotating machinery.

Module 3: Neural Networks and Deep Learning (9 Hours)

Artificial Neural Networks: Biological inspiration, Architecture of neural networks, Perceptron model, Activation functions, Forward propagation and Backpropagation concepts. Deep Learning Fundamentals: Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Deep learning frameworks overview, Hyperparameter tuning and optimization techniques. Introduction to AI-based image processing for engineering inspection, Introduction to GPU-accelerated deep learning using NVIDIA CUDA-enabled platforms, TensorFlow GPU execution, and AI workflow optimization using NVIDIA accelerated computing environments.

Engineering Applications: Surface defect detection, Structural crack identification using image analysis.

Module 4: AI Applications in Manufacturing and Mechanical Systems (9 Hours)

Predictive Maintenance and Intelligent Monitoring: Condition monitoring, Sensor-based data acquisition, Vibration analysis using AI, Remaining useful life prediction. AI in Manufacturing Systems: Smart manufacturing, Digital twins, Process optimization, Quality control using AI, Intelligent scheduling and automation. Introduction to Industrial Internet of Things (IIoT) and AI integration.

Engineering Applications: CNC machine condition monitoring, Smart production line optimization.

Module 5: Generative AI and Intelligent Design Optimization (9 Hours)

Introduction to Generative AI in Engineering: Generative design concepts, AI-assisted CAD modeling, Design space exploration, Evolutionary optimization techniques, Genetic algorithms, Multi-objective optimization. Ethics and Challenges in Engineering AI: Reliability, Explainable AI, Bias in AI systems, Sustainability and future trends in AI-enabled mechanical engineering.

Engineering Applications: Lightweight structural design, AI-assisted topology optimization.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	1	1	2	3	–	–	–	–	–	–	–	2
CO2	2	3	1	2	3	–	–	–	–	–	–	–	3
CO3	2	–	3	–	3	–	–	–	–	–	–	2	3

CO4	2	–	3	–	3	2	–	–	–	–	–	1	3
CO5	2	–	3	–	2	–	–	–	–	–	–	1	3

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand the implementation of intelligent prediction systems for mechanical engineering applications using engineering datasets and machine learning models.

Example: Implement a predictive maintenance model to identify abnormal vibration conditions in rotating machinery using machine learning algorithms:

- Import engineering sensor datasets and preprocess the data using normalization techniques.
- Develop a regression or classification model using machine learning libraries.
- Train the model using vibration and temperature datasets.
- Evaluate the model performance using the confusion matrix and accuracy metrics.
- Visualize prediction performance and interpret the engineering significance of the obtained results.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Programming: Python, Google Colab, Jupyter Notebook.
- Visualization: Matplotlib, Seaborn, Plotly.
- AI Tools: MATLAB AI Toolbox, Ansys AI-assisted optimization tools.
- NVIDIA CUDA Toolkit for GPU-accelerated engineering AI applications.
- NVIDIA Omniverse for AI-enabled engineering simulation and collaborative design.
- NVIDIA Nsight Systems for computational workflow profiling and performance analysis.

Suggested Reading

Primary Textbooks

- Rajasekaran and G. A. Vijayalakshmi Pai, “Neural Networks, Fuzzy Logic and Genetic Algorithms”, PHI Learning, 2011.
- Ethem Alpaydin, “Introduction to Machine Learning”, MIT Press, Fourth Edition, 2020.

Reference Books

- Ian Goodfellow, Yoshua Bengio and Aaron Courville, “Deep Learning”, MIT Press, 2016.
- Aurélien Géron, “Hands-On Machine Learning with Scikit-Learn, Keras and TensorFlow”, O’Reilly Media, Third Edition, 2022.
- Kevin P. Murphy, “Machine Learning: A Probabilistic Perspective”, MIT Press, 2012.

Additional Resources

- NPTEL: Artificial Intelligence and Machine Learning Courses
- Deep Learning Specialization - Coursera
- NVIDIA Developer Documentation
- NVIDIA Deep Learning Institute (DLI) Courses

DLI Course Mapped

Fundamentals of Deep Learning and Accelerated Computing
https://learn.nvidia.com/

DLI Learning Path

- Artificial Intelligence and Accelerated Computing
- AI for Manufacturing and Intelligent Systems
- Deep Learning for Mechanical System Design

Automotive Electronics and Embedded Control Systems

(As per Choice Based Credit System)	
Course Code: 26MDE5105	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Basic Electronics, Automotive Engineering Fundamentals, Microcontrollers and Embedded Systems	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to provide students with fundamental knowledge of automotive electronics and embedded control systems used in modern vehicles. The course integrates concepts of internal combustion engines, automotive subsystems, embedded hardware design, real-time systems, and system optimization techniques to develop intelligent and efficient automotive solutions.

Course Objectives

Students will be able to:

- Gain knowledge of automotive systems, internal combustion engines, and fuel management systems.
- Understand the working principles of automotive electrical, hybrid, and embedded control systems.
- Develop understanding of embedded hardware platforms and programmable logic devices.
- Analyze real-time embedded systems and scheduling techniques used in automotive applications.
- Apply modelling, optimization, and verification techniques for embedded system design.

Course Outcomes (CO)

CO	Course Outcome	BTL

CO	Course Outcome	BTL
CO1	Explain the fundamentals of internal combustion engines, fuel systems, and emission control mechanisms.	L2
CO2	Analyze electric and hybrid vehicle architectures, powertrain components, and automotive control systems.	L4
CO3	Apply embedded hardware design concepts including ASICs, ASIPs, FPGAs, and Verilog HDL.	L3
CO4	Apply microcontroller, real-time operating system, and real-time scheduling concepts to embedded automotive applications.	L3
CO5	Apply embedded system modelling, partitioning, optimization, and verification techniques for efficient system design.	L3

Broad Course Description

This course introduces automotive electronics and embedded control systems with emphasis on intelligent vehicle technologies and real-time embedded applications. The course covers fundamentals of internal combustion engines, automotive subsystems, electric and hybrid vehicle technologies, and embedded hardware design methodologies. Students gain knowledge of embedded processors, RTOS concepts, scheduling algorithms, and system-level optimization techniques. The course prepares students to design and analyze embedded automotive systems for modern transportation applications.

Detailed Course Syllabus

Course Modules

Module 1: Internal Combustion Engines and Fuel Systems (9 Hours)

Classification of Internal Combustion Engines, Engine Components, Two Stroke and Four Stroke Engines, Engine Cycles, Engine Performance, Combustion in Spark Ignition and Compression Ignition Engines, Fuel Introduction Systems, Engine Emissions and Emission Control Systems.

Engineering Applications: Electronic Fuel Injection Systems, Engine Monitoring Systems, Emission Control and Performance Analysis in Automobiles.

Module 2: Automotive Systems and Electric/Hybrid Vehicles (9 Hours)

Automotive Powertrain, Clutch and Transmission Systems, Brake Systems: Hydraulic Brake, Air Brake, ABS, Steering Systems and Wheel Alignment, Suspension Systems, Introduction to Electric and Hybrid Powertrain, Tyres.

Engineering Applications: Anti-lock Braking Systems, Electric Vehicle Drive Systems, Steering and

Suspension Monitoring Systems.

Module 3: Introduction to Embedded Systems and Hardware Design (9 Hours)

Introduction to Embedded Systems, ASICs and ASIPs, Single Purpose Processor Design, Introduction to FPGAs, Verilog HDL Basics.

Engineering Applications: FPGA-based Automotive Controllers, Embedded Hardware for Vehicle Monitoring Systems, Digital Control Unit Design.

Module 4: Embedded Processors and Real Time Systems (9 Hours)

Microcontrollers, Power Aware Embedded System Design, Real Time Operating System, Real Time Scheduling Algorithms.

Engineering Applications: Automotive ECU Design, Real-Time Vehicle Control Systems, Embedded Controllers for Smart Automotive Applications.

Module 5: Embedded System Modelling and Optimization (9 Hours)

Modelling and Specification, Design Synthesis, Hardware Software Partitioning, Design Optimization, Simulation and Verification.

Engineering Applications: Embedded Automotive System Optimization, Hardware-Software Co-design for Intelligent Vehicles, Simulation of Automotive Embedded Platforms.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	2	–	2	–	–	–	–	–	–	–	–
CO2	2	3	2	–	2	–	–	–	–	–	–	–	3
CO3	2	–	3	–	1	–	–	–	–	–	–	1	–
CO4	2	3	1	–	1	–	–	–	–	–	–	–	–
CO5	2	–	3	–	2	–	–	–	–	–	–	1	2

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

Implement a simple engine performance monitoring system:

- Accept engine parameters as input
- Analyze fuel efficiency and emissions
- Identify abnormal engine conditions
- Display diagnostic information

Develop a vehicle subsystem monitoring application:

- Simulate braking and steering operations
- Monitor suspension parameters
- Analyze hybrid/electric vehicle power usage
- Display system performance metrics

Design a basic embedded hardware module:

- Model simple digital circuits using Verilog HDL
- Simulate FPGA-based control logic
- Implement embedded control operations
- Analyze hardware resource utilization

Develop a real-time embedded application:

- Simulate task scheduling

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- MATLAB / Simulink
- Keil µVision IDE
- Xilinx Vivado / Quartus Prime
- Proteus Simulation Software
- Embedded C Programming Tools

Suggested Reading

Primary Textbooks

- William B. Ribbens, Understanding Automotive Electronics, Elsevier.
- Raj Kamal, Embedded Systems: Architecture, Programming and Design, McGraw Hill.

Reference Books

- Ronald K. Jurgen, Automotive Electronics Handbook, McGraw Hill.
- Frank Vahid and Tony Givargis, Embedded System Design, Wiley.
- David E. Simon, An Embedded Software Primer, Pearson.
- Yashwant Kanetkar, Embedded Systems, BPB Publications.
- R. Bosch GmbH, Automotive Handbook, SAE Publications.

Additional Resources

- NPTEL Courses on Embedded Systems
- NPTEL Courses on Automotive Engineering
- ARM Embedded System Documentation
- FPGA and Verilog HDL Tutorials
- Automotive Embedded Systems Research Papers

DLI Course Mapped

Fundamentals of Deep Learning for Embedded Systems
https://learn.nvidia.com/

DLI Learning Path

- AI for Automotive Embedded Systems
- Intelligent Vehicle Control Systems
- Edge AI for Automotive Electronics

Product Design and Development Methodologies

(As per Choice Based Credit System)	
Course Code: 26MDE5106	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Drawing / Basic Design	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course cultivates the ability to systematically design, prototype, and develop products by integrating creative thinking, engineering principles, and user-centric methodologies. Learners will gain proficiency in applying structured design processes — from ideation to market-ready prototypes — while leveraging modern AI-powered simulation tools and digital twin environments. The course prepares students to lead cross-functional design teams and contribute to innovation-driven product ecosystems in a competitive global market.

Course Objectives

Students will be able to:

- Understand the complete product design and development lifecycle from concept to commercialization.
- Apply design thinking and user-centered design principles to identify and solve real-world problems.
- Demonstrate proficiency in ideation, sketching, prototyping, and iterative refinement techniques.
- Evaluate and apply various product development methodologies including Agile, Stage-Gate, and Lean development.
- Utilize AI-driven tools and digital twin technologies for simulation-based product validation and optimization.

Course Outcomes (CO)

CO	Course Outcome	BTL

CO	Course Outcome	BTL
CO1	Explain design thinking, human-centered design principles, and user research methods used to formulate product problem statements and generate creative concepts.	L2
CO2	Analyze product development methodologies (Stage-Gate, Agile, Lean) and select appropriate models for different project contexts and constraints.	L4
CO3	Apply concept generation and selection tools, GD&T, design for X (DFM, DFA, DFS), and cost estimation methods to develop detailed product designs.	L3
CO4	Apply rapid prototyping, product testing, validation methods, and FMEA to verify product performance, reliability, and compliance with standards.	L3
CO5	Implement NVIDIA Omniverse digital twin workflows to simulate, validate, and optimize product designs before physical manufacturing.	L3

Broad Course Description

This course provides a comprehensive introduction to the principles and practices of product design and development. Students are guided through the complete new product development (NPD) lifecycle — from understanding customer needs and ideation, through conceptual design and detailed engineering, to prototyping, testing, and market launch strategies.

Learners will be equipped with hands-on skills in design tools, prototyping methods, and product validation techniques. Core topics include Design Thinking, Quality Function Deployment (QFD), TRIZ, Design for

X (DFX), Failure Mode and Effect Analysis (FMEA), and Agile/Stage-Gate project management methodologies.

The course integrates AI-driven design tools and NVIDIA Omniverse's digital twin environment to simulate product behavior in virtual spaces, enabling rapid iteration and validation before physical prototyping. Through industry-linked case studies and team-based projects, students develop the competencies required to lead product innovation in engineering, consumer electronics, automotive, and healthcare sectors.

Detailed Course Syllabus

Course Modules

Module 1: Introduction to Product Design and Design Thinking (9 Hours)

Introduction to Product Design: Definition, scope, and importance of product design and development. Types of products: consumer, industrial, medical, and digital. Overview of the New

Product Development (NPD) process. Product lifecycle: introduction, growth, maturity, decline. Design Thinking Framework: Empathize, Define, Ideate, Prototype, Test. Human-centered design principles and user research methods (interviews, surveys, ethnography). Problem statement formulation and opportunity identification. Creativity tools: SCAMPER, brainstorming, mind mapping, morphological analysis.

Engineering Applications: Smart home device concept development, wearable health monitoring device ideation.

Module 2: Product Development Methodologies and Planning (9 Hours)

New Product Development Models: Sequential (Waterfall) model vs. iterative models. Stage-Gate® model: phases, gates, and decision criteria. Agile Product Development: Scrum, Kanban, and sprint-based design cycles. Lean Product Development: value stream mapping, waste elimination. Customer Voice Integration: Quality Function Deployment (QFD), House of Quality. Voice of Customer (VoC) analysis and competitive benchmarking. Market analysis, product specification, and target costing. Intellectual Property basics: patents, trade secrets, and design rights.

Engineering Applications: Automotive dashboard design using Stage-Gate, IoT device development using Agile sprints.

Module 3: Conceptual Design and Detailed Engineering (9 Hours)

Concept Generation and Selection: Functional decomposition and morphological charts. Concept screening (Pugh matrix) and concept scoring. TRIZ (Theory of Inventive Problem Solving): contradiction matrix and inventive principles. Detailed Design: Engineering drawings, GD&T (Geometric Dimensioning and Tolerancing). Material selection criteria: mechanical, thermal, chemical, and sustainability properties. Design for X (DFX): Design for Manufacturability (DFM), Design for Assembly (DFA), Design for Sustainability (DFS). Cost estimation methods: parametric, analogical, and bottom-up costing.

Engineering Applications: Ergonomic chair design using DFM/DFA, material selection for a portable solar charger.

Module 4: Prototyping, Testing, and Validation (9 Hours)

Prototyping Methods: Types of prototypes: proof-of-concept, appearance, functional, and pre-production. Rapid prototyping techniques: FDM 3D printing, SLA, SLS, CNC machining. Low-fidelity vs. high-fidelity prototyping. Product Testing and Validation: Engineering testing: stress analysis, fatigue testing, thermal testing. User testing: usability testing, A/B testing, and user acceptance testing (UAT). Failure Mode and Effect Analysis (FMEA): process FMEA and design FMEA. Reliability engineering: MTBF, failure rate analysis. Regulatory standards and certifications: ISO, BIS, CE, UL.

Engineering Applications: 3D-printed medical device prototype validation, FMEA for a consumer electronics product.

Module 5: Digital Twins and AI in Product Design (9 Hours)

Digital Twins: Definition, types (product, process, and system digital twins), and their role in accelerating product development cycles. NVIDIA Omniverse and the OpenUSD framework for product simulation and visualization: creating digital twin models of product assemblies. Real-time physics simulation: collision detection, material behavior, and stress simulation. AI-Driven Design: Generative design using AI optimization algorithms and AI-powered design validation. Connecting IoT sensor data to digital twins for real-time monitoring and simulation-driven design iteration.

Engineering Applications: Digital twin of an industrial robotic arm assembly, AI-generated packaging design optimization.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	1	3	–	1	–	–	–	–	–	–	2	–
CO2	2	3	3	–	2	–	–	–	–	–	–	3	3
CO3	2	3	3	–	1	–	–	–	–	–	–	3	3
CO4	2	3	3	–	2	–	3	–	–	–	–	3	3
CO5	2	–	3	2	3	–	–	–	–	–	–	3	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Understand how generative AI and simulation-based reasoning power next-generation product design — where user need → AI-generated concept → simulation validation → optimized design mirrors the iterative intelligence of modern engineering.

Example: Apply AI-driven Generative Design to optimize a bicycle frame bracket using topology optimization:

- Define the design space: specify fixed and load points, material constraints (Aluminum 6061-T6), and performance goals.
- Run a generative design algorithm that explores thousands of geometric forms and selects those meeting weight and stress thresholds.
- Visualize and compare AI-generated design candidates using NVIDIA Omniverse real-time rendering.
- Perform digital twin simulation to validate structural integrity under dynamic loading conditions.
- Compare AI-generated result with manual DFM analysis and derive manufacturing feasibility score.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- CAD/3D Modeling: SolidWorks, Fusion 360, CATIA, FreeCAD
- Prototyping: FDM 3D Printers, Laser Cutters, CNC Milling
- Simulation: ANSYS, SimScale, NVIDIA Omniverse
- Design Thinking: Miro, FigJam, Lucidchart
- AI Design: Autodesk Generative Design, nTopology, DALL-E for concept sketching
- Project Management: Jira, Trello, MS Project

Suggested Reading

Reference Books

- Tim Brown, “Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation”, Harper Business, 2009.

- Clive L. Dym, Patrick Little, Elizabeth J. Orwin, "Engineering Design: A Project-Based Introduction", Wiley, 4th Edition, 2014.
- David G. Ullman, "The Mechanical Design Process", McGraw-Hill, 4th Edition, 2010.

Additional Resources

- NPTEL - Product Design and Manufacturing, IIT Delhi: https://nptel.ac.in
- MIT OpenCourseWare - Design and Manufacturing II: https://ocw.mit.edu
- IIT Bombay - New Product Development (NPTEL): https://nptel.ac.in/courses/110101010
- NIT Calicut - Engineering Design: http://www.nitc.ac.in

DLI Course Mapped

Building Digital Twins for Physical AI With NVIDIA Omniverse

DLI Learning Path

- Digital Twins for Physical AI
- AI-Assisted Product Design and Development
- Digital Prototyping and Virtual Testing

Industrial Design, Ergonomics and Human-Centered Engineering

(As per Choice Based Credit System)	
Course Code: 26MDE5107	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Fundamentals of Mechanical Engineering and Product Design	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs. **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course develops the ability to integrate industrial design principles, ergonomics, and human-centered engineering approaches into the development of efficient, safe, sustainable, and user-friendly mechanical products and systems. The learners gain knowledge in product aesthetics, usability, anthropometry, cognitive ergonomics, and user experience-driven engineering design for modern industrial applications.

Course Objectives

Students will be able to:

- Understand the principles of industrial design and human-centered engineering in product development.
- Explore ergonomics and anthropometric considerations for safe and efficient system design.
- Demonstrate design thinking methodologies for user-oriented engineering applications.
- Apply cognitive and physical ergonomics concepts in industrial product and workplace design.
- Introduce sustainable and inclusive design practices for modern engineering systems.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the principles of industrial design, form and aesthetics, and user-centered design used in engineering products and systems.	L2
CO2	Apply anthropometric data, biomechanical principles, and posture-	L3

CO	Course Outcome	BTL
	analysis methods to workplace and product design.	
CO3	Analyze human–machine interaction, cognitive workload, and usability test results to develop human-centered design solutions.	L4
CO4	Apply eco-design principles, lifecycle assessment, and design for manufacturability and assembly to the design and material selection of sustainable products.	L3
CO5	Apply digital human modeling, AR/VR-based ergonomic evaluation, and universal design principles to smart human–machine collaboration.	L3

Broad Course Description

This course introduces students to the concepts of industrial design, ergonomics, and human-centered engineering for developing efficient and user-friendly mechanical systems and products. The course focuses on integrating aesthetics, usability, safety, comfort, and sustainability into engineering design processes.

Learners will gain knowledge in product design methodologies, ergonomic evaluation techniques, anthropometric analysis, workplace design, cognitive ergonomics, and user experience engineering. The course also emphasizes design thinking, sustainable product development, universal design principles, and modern human-machine interaction concepts.

Through theoretical concepts, industrial case studies, and design-oriented discussions, the course nurtures the ability to create innovative engineering products that improve functionality, user satisfaction, and operational efficiency.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Industrial Design and Human-Centered Engineering (9 Hours)

Introduction to Industrial Design: Evolution and importance of industrial design, Product development cycle, Design elements and principles, Form and aesthetics in engineering products, User-centered product development. Human-centered engineering concepts, Design thinking process, Creativity and innovation methods, Engineering design communication and visualization techniques.

Engineering Applications: Consumer product design, Automotive interior systems.

Module 2: Ergonomics and Anthropometry (9 Hours)

Introduction to Ergonomics: Physical ergonomics, Cognitive ergonomics, Organizational ergonomics. Anthropometry and biomechanical principles, Human body dimensions and measurements, Posture analysis, Musculoskeletal disorders, Workplace ergonomics and safety standards. Ergonomic assessment methods and ergonomic risk analysis.

Engineering Applications: Industrial workstation design, Machine tool operator safety systems.

Module 3: Human Factors and Usability Engineering (9 Hours)

Human factors engineering concepts, Human-machine interaction, Human information processing system, Cognitive workload and fatigue analysis, User interface design principles, Usability testing methods, User experience (UX) engineering, Safety and reliability in human-machine systems, Design for accessibility and inclusiveness.

Engineering Applications: Aircraft cockpit ergonomics, Human-machine interfaces in manufacturing systems.

Module 4: Product Design and Sustainable Engineering (9 Hours)

Product design methodologies, Sustainable product development, Eco-design principles, Lifecycle assessment, Design for manufacturability and assembly, Materials selection in industrial design, Emotional design and branding, Packaging and product presentation concepts. Introduction to digital design tools and prototyping techniques.

Engineering Applications: Sustainable consumer appliances, Eco-friendly industrial equipment design.

Module 5: Advanced Trends in Ergonomics and Human-Centered Design (9 Hours)

Virtual ergonomics and digital human modeling, Smart wearable systems, Augmented reality and virtual reality in ergonomic evaluation, Industry 4.0 and smart human-machine collaboration, Universal design principles, Inclusive engineering design, Ethical considerations in human-centered systems and future trends in industrial design engineering.

Engineering Applications: Smart assistive devices, Collaborative robotic systems.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	–	3	–	1	–	–	–	–	–	–	2	–
CO2	2	3	3	–	1	–	–	–	–	–	–	3	3
CO3	2	–	3	–	1	–	–	–	–	–	–	1	–
CO4	2	2	1	–	1	–	–	–	–	–	–	–	3
CO5	2	–	3	–	2	–	3	–	–	–	–	2	–

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand how AI-assisted ergonomic analysis and user behavior prediction

improve industrial product and workplace design.

Example:

- Collect anthropometric and ergonomic assessment data.
- Analyze posture-related risk factors using AI-assisted ergonomic tools.
- Develop a predictive model for identifying operator discomfort levels.
- Evaluate usability and safety performance using engineering metrics.
- Interpret the obtained results for human-centered product improvement.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
Grand Total	—	—	**100**	—

Recommended Tools

- CATIA / SolidWorks
- Siemens Jack / CATIA Human Builder
- MATLAB Ergonomics Toolboxes
- Digital Human Modeling Tools
- NVIDIA Omniverse for collaborative industrial design visualization
- NVIDIA Isaac Sim for human-machine interaction and robotics simulation

Suggested Reading

Primary Textbooks

- Stephen Pheasant and Christine Haslegrave, “Bodyspace: Anthropometry, Ergonomics and the Design of Work”, CRC Press.
- Karl T. Ulrich and Steven D. Eppinger, “Product Design and Development”, McGraw Hill.

Reference Books

- Gavriel Salvendy, “Handbook of Human Factors and Ergonomics”, Wiley.
- George E. Dieter, “Engineering Design”, McGraw Hill.
- Don Norman, “The Design of Everyday Things”, Basic Books.

Additional Resources

- NPTEL: Ergonomics for Beginners
- MIT Open CourseWare - Product Design
- Human Factors and Ergonomics Society Resources

DLI Course Mapped

NVIDIA Omniverse and AI for Industrial Digitalization
https://learn.nvidia.com/

DLI Learning Path

- Human-Centered AI and Intelligent Design Systems
- AI-Assisted Ergonomic Analysis
- Digital Human Modeling for Product Design

Advanced Vibro-Acoustic Engineering

(As per Choice Based Credit System)	
Course Code: 26MDE5108	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mathematics, Theory of Vibrations, Acoustics, Numerical Methods	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course develops the ability to analyze coupled vibration and acoustic systems, predict noise generation and transmission, and design engineering solutions for noise and vibration control in machinery, vehicles, structures, and products.

Course Objectives

Students will be able to:

- Formulate the governing equations of vibration and acoustics for engineering systems using energy methods and wave concepts.
- Analyze vibration response, wave propagation, sound radiation, and transmission characteristics of engineering systems.
- Evaluate coupled structural-acoustic behavior, modal response, damping, resonance, and transmission loss.
- Interpret experimental and numerical vibro-acoustic data using FRF, FFT, modal parameters, and noise metrics.
- Apply computational and data-driven methods for vibro-acoustic prediction, diagnosis, and design improvement.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the governing relations of vibrating and acoustic systems, including damping, resonance, transmissibility, and acoustic field	L2

CO	Course Outcome	BTL
	variables.	
CO2	Analyze the response of SDOF, MDOF, and continuous systems to harmonic, transient, and random excitation.	L4
CO3	Derive and interpret structural-acoustic coupling, sound radiation, and transmission loss relations for engineering systems.	L4
CO4	Apply vibro-acoustic measurement techniques, FRF estimation, modal testing, and signal processing to characterize structural and acoustic responses.	L3
CO5	Analyze noise, vibration, and acoustic design options using FEM/BEM, statistical energy analysis, and data-driven tools.	L4

Broad Course Description

This course introduces advanced principles of vibrations and acoustics with emphasis on coupled structural-acoustic behavior, sound radiation, transmission, and control. It integrates analytical formulation, experimental interpretation, and modern simulation-based reasoning so that learners can evaluate how geometry, material properties, boundary conditions, damping, and excitation govern noise and vibration performance. The course is intended for postgraduate learners and is aligned with outcome-based education practices through measurable COs, internal assessment, and semester-end evaluation.

Detailed Course Syllabus

Course Modules

Module 1: Foundations of Vibration and Acoustics (9 Hours)

Review of vibrating systems, harmonic motion, damping models, resonance, transmissibility, and vibration isolation. Acoustic field variables, sound pressure, particle velocity, acoustic impedance, plane waves, spherical waves, sound power, sound pressure level, decibel scales, and basic radiation concepts. Introductory treatment of wave propagation in fluids and solids.

Engineering Applications: rotating machines, ducts, enclosures, precision instruments, and noise control in compact devices

Module 2: Structural Vibration and Wave Propagation (9 Hours)

Single- and multi-degree-of-freedom systems, mode shapes, frequency response functions, modal superposition, and response to base excitation. Beam vibration using Euler-Bernoulli and Timoshenko models, dispersion relations, structural waves, dynamic stiffness ideas, and absorbers. Introduction to damping treatments and passive isolation strategies.

Engineering Applications: machine foundations, beams, panels, automotive body components, and vibration isolation mounts

Module 3: Structural-Acoustic Coupling and Sound Radiation (9 Hours)

Coupled vibro-acoustic equations, cavity modes, panel-cavity interaction, radiation efficiency, acoustic impedance matching, transmission loss, and boundary condition effects. Sound absorption, lining materials, enclosure acoustics, and basic control of airborne and structure-borne noise.

Engineering Applications: vehicle cabins, equipment housings, wall partitions, appliance enclosures, and machine guarding

Module 4: Vibro-Acoustic Measurement Principles and Signal Analysis (9 Hours)

Instrumentation for vibration and acoustic measurements, accelerometers, microphones, force transducers, data acquisition, FFT analysis, octave and third-octave bands, coherence, FRF estimation, modal testing, and source identification. Noise metrics, sound quality indicators, and introductory psychoacoustics for engineering judgment.

Engineering Applications: noise mapping, condition monitoring, product benchmarking, and validation of simulation models

Module 5: Computational and Design Methods for Vibro-Acoustics (9 Hours)

Finite element and boundary element methods for coupled problems, model reduction, sub-structuring, statistical energy analysis, sensitivity studies, optimization concepts, uncertainty awareness, and active noise control fundamentals. Overview of digital workflow for model verification, result interpretation, and design iteration.

Engineering Applications: aerospace panels, vehicle NVH, structural enclosures, product design, and noise reduction engineering

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	–	3	–	1	–	1	–	–	–	–	–	2
CO2	2	3	–	–	1	–	–	–	–	–	–	–	–
CO3	2	2	1	–	1	–	–	–	–	–	–	–	2
CO4	2	3	–	2	2	–	–	–	–	–	–	–	3
CO5	2	–	3	2	3	–	–	–	–	–	–	2	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

Aim: Understand how data-driven methods complement analytical and numerical vibro-acoustic analysis in modern engineering practice.

- Generate a small training set from simulation or experimental data and fit a regression model to estimate sound pressure level, vibration amplitude, or transmissibility.
- Use vibration or spectrogram data to classify operating states, imbalance, looseness, or support-condition changes.

- Compare analytical, numerical, and AI-assisted predictions, and discuss error, robustness, and interpretability.
- Build a simple digital-twin style workflow in which measured signals update model parameters for response prediction and diagnosis.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Vibration and acoustic software: ABAQUS/ANSYS, COMSOL Multiphysics, Actran, Simcenter 3D, LMS Virtual.Lab, or equivalent.
- Programming and analytics: Python, MATLAB, NumPy, SciPy, and spreadsheet-based verification.
- AI tools: scikit-learn, basic deep learning libraries, and notebook environments for data handling and visualization.

Suggested Reading

Primary Textbooks

- M. L. Munjal, Acoustics of Ducts and Mufflers, Wiley.
- L. E. Kinsler, A. R. Frey, A. B. Coppens and J. V. Sanders, Fundamentals of Acoustics, Wiley.

Reference Books

- F. Fahy and P. Gardonio, Sound and Structural Vibration: Radiation, Transmission and Response, Academic Press.
- D. J. Inman, Engineering Vibration, Pearson.
- M. J. Crocker (Ed.), Handbook of Noise and Vibration Control, Wiley.

Additional Resources

- NPTEL modules on vibrations, acoustics, and noise control.
- Vendor manuals and benchmark examples from vibro-acoustic software packages.

DLI Course Mapped

Fundamentals of Accelerated Computing for Simulation
https://learn.nvidia.com/

DLI Learning Path

- Accelerated Computing for Vibro-Acoustic Simulation
- AI-Assisted Noise and Vibration Diagnostics
- Physics-Informed Machine Learning for Acoustics

Reliability Engineering and Failure Diagnostics

(As per Choice Based Credit System)	
Course Code: 26MDE5109	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mathematics, Basic Mechanical Engineering, Probability & Statistics	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course develops advanced analytical competencies in reliability engineering and failure diagnostics, enabling M.Tech students to design robust, highly dependable engineering systems and efficiently diagnose complex failure modes across industrial domains. Students will master quantitative reliability modeling, life data analysis, and AI-assisted failure detection to minimize unplanned downtime, optimize maintenance strategies, and improve product lifecycle performance. The course bridges classical reliability theory with modern Industry 4.0 practices, equipping graduates with skills directly applicable to aerospace, automotive, manufacturing, power systems, and medical device industries.

Course Objectives

Students will be able to:

- Understand the fundamental concepts of reliability, maintainability, and availability in engineering systems.
- Apply statistical distributions (Weibull, exponential, lognormal) for life data analysis and failure prediction.
- Demonstrate the use of Failure Mode and Effect Analysis (FMEA), Fault Tree Analysis (FTA), and Root Cause Analysis (RCA) for failure diagnostics.
- Analyze and design preventive, predictive, and condition-based maintenance strategies using reliability-centered maintenance (RCM) principles.
- Implement AI-driven anomaly detection and remaining useful life (RUL) estimation using LSTM and autoencoder models for predictive maintenance.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain fundamental reliability concepts, including the reliability function, hazard rate, MTTF, and MTBF, used to describe engineering system performance.	L2
CO2	Analyze failure-time data using Weibull, exponential, and lognormal distributions and determine the reliability of series, parallel, k-out-of-n, and complex network systems.	L4
CO3	Perform systematic failure diagnostics using FMEA, FTA, RCA, and FMECA to identify, prioritize, and mitigate failure modes in mechanical and electronic systems.	L4
CO4	Apply reliability-centered maintenance (RCM) and condition-based maintenance (CBM) strategies to industrial systems using quantitative methods.	L3
CO5	Analyze time-series sensor data using LSTM networks and autoencoders to estimate remaining useful life (RUL) and detect anomalies for AI-driven predictive maintenance.	L4

Broad Course Description

This course provides an in-depth treatment of reliability engineering and failure diagnostics as applied to complex engineering systems. Students are introduced to the mathematical foundations of reliability theory, covering failure distributions, life data analysis, hazard modeling, and system reliability evaluation across series, parallel, and complex configurations.

The course advances into structured failure diagnostic methodologies — FMEA, Fault Tree Analysis, Event Tree Analysis, Root Cause Analysis, and FMECA — and connects them to practical reliability-centered maintenance (RCM) frameworks. Topics in accelerated life testing (ALT), design for reliability (DFR), and the Weibull analysis toolkit are covered with industry applications in aerospace, automotive, power systems, and manufacturing.

A distinguishing feature of this course is its integration of AI and deep learning for failure diagnostics. Students will use NVIDIA RAPIDS-accelerated XGBoost models, LSTM-based failure prediction networks, and autoencoder anomaly detection on industrial time-series sensor datasets — gaining hands-on exposure to modern predictive maintenance platforms directly aligned with the NVIDIA DLI curriculum.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Reliability Engineering (9 Hours)

Introduction to Reliability: Definition, scope, and importance of reliability engineering; reliability vs. quality vs. safety. Reliability metrics: MTTF, MTBF, availability, and maintainability. Bathtub curve: infant mortality, useful life, and wear-out phases. Failure rate and hazard function; reliability function R(t) and failure density f(t). Failure distributions: exponential, Weibull, lognormal, and normal. Parameter estimation using probability plotting and maximum likelihood; treatment of censored data; goodness-of-fit tests (Kolmogorov–Smirnov).

Engineering Applications: Bearing life analysis using Weibull distribution, turbine blade reliability modeling.

Module 2: System Reliability and Life Data Analysis (9 Hours)

System Reliability Modeling: Series, parallel, series-parallel, and k-out-of-n configurations; reliability block diagrams (RBD); complex systems using minimal cut sets and path sets; common-cause failures; Monte Carlo simulation for system reliability estimation. Life Data Analysis (LDA): Accelerated Life Testing (ALT) with constant and step stress; Arrhenius and inverse power law models; confidence bounds; reliability demonstration testing and sample size determination. Overview of reliability growth (Crow-AMSAA) and software-based life data analysis workflow.

Engineering Applications: Power grid reliability modeling (k-out-of-n), semiconductor ALT with Arrhenius model

Module 3: Failure Mode Analysis and Failure Diagnostics (9 Hours)

Failure Mode and Effect Analysis (FMEA): Process FMEA vs. Design FMEA; Risk Priority Number (RPN); FMECA criticality analysis. Fault Tree Analysis (FTA): Boolean logic, minimal cut sets, and quantitative top-event probability; event tree analysis and bow-tie diagrams. Root Cause Analysis (RCA): Ishikawa (fishbone) diagram, 5-Why analysis, and physical, human, and systemic root causes. Failure Diagnostics: Overview of NDT methods (ultrasonic, radiographic, eddy current, thermographic), vibration signature analysis, and oil particle analysis. Case studies: gear tooth failure, fatigue crack propagation, bearing spalling diagnosis.

Engineering Applications: FMEA for automotive brake system, FTA for nuclear reactor safety system, RCA for jet engine failure.

Module 4: Maintenance Strategies and Reliability-Centered Maintenance (9 Hours)

Maintenance Philosophy: Corrective, preventive, predictive, and proactive maintenance. Reliability-Centered Maintenance (RCM): Functions, functional failures, failure effects and consequences; RCM decision logic (hidden vs. evident failures, safety vs. economic consequences); overview of MSG-3 for aviation maintenance. Condition-Based Maintenance (CBM): Condition monitoring parameters (vibration, temperature, pressure, oil analysis), health index models, and decision thresholds. Prognostics and Health Management (PHM): Remaining Useful Life (RUL) concepts; physics-of-failure vs. data-driven models. Maintenance Optimization: Age and block replacement policies; cost-benefit analysis of maintenance strategies.

Engineering Applications: CBM program for a chemical process plant, RCM analysis for railway rolling stock.

Module 5: AI-Driven Failure Diagnostics and Predictive Maintenance (9 Hours)

AI in Reliability: Limitations of traditional maintenance and the role of machine learning and deep

learning in failure diagnostics. Time-Series Data for Failure Prediction: Sensor data acquisition, preprocessing, and feature engineering; handling imbalanced failure datasets; GPU-accelerated data processing using NVIDIA RAPIDS. Machine Learning for Failure Classification: XGBoost ensemble models, cross-validation, and performance metrics (ROC-AUC, precision-recall, confusion matrix). Deep Learning for Failure Diagnostics: LSTM networks for sequential failure patterns and autoencoder-based anomaly detection. Remaining Useful Life (RUL) Estimation: Health indicator construction from multi-sensor data, LSTM-based RUL prediction, and deployment for real-time predictive maintenance dashboards.

Engineering Applications: LSTM-based bearing failure prediction (PRONOSTIA/FEMTO dataset), XGBoost model for CNC tool wear classification.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	2	1	–	1	–	–	–	–	–	–	–	2
CO2	2	3	–	3	3	–	–	–	–	–	–	–	3
CO3	2	3	–	–	2	–	–	–	–	–	–	–	2
CO4	2	3	3	–	2	–	–	–	–	–	–	2	3
CO5	2	–	3	2	2	–	–	–	–	–	–	–	–

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Demonstrate how AI and deep learning mirror the logic of condition-based reasoning in reliability engineering — where sensor data → feature extraction → anomaly detection → RUL prediction → maintenance action replicates the engineer's diagnostic intelligence at machine scale.

Example: Implement a GPU-accelerated predictive maintenance pipeline for a rotating machinery dataset:

- Ingest multi-channel vibration and temperature time-series data from industrial sensors using NVIDIA RAPIDS cuDF for fast preprocessing.
- Engineer features (RMS, kurtosis, peak-to-peak, frequency domain features via FFT) from raw sensor streams.
- Train an XGBoost classification model to distinguish healthy vs. degraded operational states; evaluate performance using ROC-AUC and precision-recall curves.
- Design and train an LSTM autoencoder on 'normal' operational data; flag anomalies where reconstruction error exceeds a statistically derived threshold.

- Build an LSTM regression model to estimate Remaining Useful Life (RUL) and trigger maintenance alerts when predicted RUL falls below a defined safety margin.
- Visualize model predictions on a real-time monitoring dashboard and compare against classical Weibull-based RUL estimates.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Reliability Analysis: ReliaSoft Weibull++, Reliasoft BlockSim, MATLAB Reliability Toolbox

- Data Processing: Python (NumPy, Pandas), NVIDIA RAPIDS cuDF
- AI / Deep Learning: TensorFlow, Keras, XGBoost, scikit-learn
- Simulation: MATLAB, Python (Monte Carlo with NumPy), SimScale
- Vibration Analysis: LabVIEW, MATLAB Signal Processing Toolbox
- FMEA / FTA: Relyence FMEA, Isograph FaultTree+, Windchill FMEA

Suggested Reading

Primary Textbooks

- Blischke, W.R. and Murthy, D.N.P., "Reliability: Modeling, Prediction, and Optimization", Wiley-Interscience, 2000.
- Ebeling, C.E., "An Introduction to Reliability and Maintainability Engineering", McGraw-Hill, 2nd Edition, 2010.

Reference Books

- O'Connor, P.D.T. and Kleyner, A., "Practical Reliability Engineering", Wiley, 5th Edition, 2012.
- Moubray, J., "Reliability-Centered Maintenance", Industrial Press, 2nd Edition, 1997.
- Nelson, W.B., "Accelerated Testing: Statistical Models, Test Plans, and Data Analysis", Wiley, 2004.
- Mobley, R.K., "Root Cause Failure Analysis", Butterworth-Heinemann, 1999.

Additional Resources

- NPTEL – Reliability Engineering, IIT Kharagpur
- NPTEL – Maintenance Engineering, IIT Madras
- NASA C-MAPSS Turbofan Engine Dataset
- PRONOSTIA Bearing Dataset (FEMTO-ST Institute)
- ReliaSoft Life Data Analysis Reference

DLI Course Mapped

Applications of AI for Predictive Maintenance

DLI Learning Path

- Data Science for Reliability Engineering
- AI-Assisted Predictive Maintenance
- Failure Diagnostics using Machine Learning

Smart Sensors and Industrial Instrumentation Systems

(As per Choice Based Credit System)	
Course Code: 26MDE5110	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Basic Electrical Engineering, Sensors & Measurements, Automation Fundamentals	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop industry-oriented knowledge and practical competency in smart sensing technologies, industrial instrumentation systems, industrial automation, and intelligent monitoring systems using Bosch Rexroth industrial practices. The course enables students to understand modern sensor technologies, data acquisition systems, industrial communication, and Industry 4.0-based instrumentation for real-time industrial applications.

Course Objectives

Students will be able to:

- Understand the fundamentals of smart sensors and industrial instrumentation systems.
- Learn industrial sensing techniques for measurement, monitoring, and automation.
- Develop practical skills in industrial signal conditioning, calibration, and data acquisition systems.
- Apply industrial communication protocols and intelligent automation systems in manufacturing industries.
- Implement Industry 4.0-enabled smart monitoring and predictive maintenance systems using modern instrumentation technologies.

Course Outcomes (CO)

CO	Course Outcome	BTL

CO	Course Outcome	BTL
CO1	Explain the classification, static and dynamic characteristics, and measurement principles of smart sensors and industrial instrumentation systems.	L2
CO2	Apply industrial sensors and signal conditioning techniques to measurement and monitoring applications.	L3
CO3	Analyze data acquisition systems and industrial instrumentation architectures, including A/D conversion, calibration, SCADA, and PLC integration, for process measurement.	L4
CO4	Apply industrial communication protocols and automation techniques to integrated instrumentation systems.	L3
CO5	Analyze AI-enabled intelligent monitoring and predictive maintenance systems for industrial equipment.	L4

Broad Course Description

The Smart Sensors and Industrial Instrumentation Systems course provide comprehensive knowledge of modern industrial sensing technologies, instrumentation systems, and intelligent automation practices adopted in industries such as manufacturing, process industries, robotics, and smart factories.

The course covers sensor fundamentals, industrial transducers, signal conditioning, calibration techniques, data acquisition systems, PLC-integrated instrumentation, industrial communication protocols, IoT-enabled smart sensors, and predictive maintenance systems. Students gain hands-on exposure to Bosch Rexroth industrial automation concepts and real-time monitoring systems used in Industry 4.0 environments.

The course integrates AI-enabled monitoring systems, intelligent industrial diagnostics, and smart manufacturing applications to prepare students for industrial automation and digital manufacturing domains.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Smart Sensors and Instrumentation (9 Hours)

Introduction to sensors and transducers, classification of sensors, smart sensors, characteristics of sensors, static and dynamic characteristics, industrial instrumentation systems, measurement principles, sensor calibration, error analysis, industrial standards and safety.

Engineering Applications: Calibration and error analysis of pressure and temperature transmitters

in process plants, sensor selection for machine condition monitoring, and instrumentation safety practices in manufacturing plants.

Module 2: Industrial Sensors and Signal Conditioning (9 Hours)

Temperature sensors, pressure sensors, flow sensors, proximity sensors, displacement sensors, vibration sensors, optical sensors, strain gauges, load cells, signal conditioning circuits, amplifiers, filters, noise reduction techniques.

Engineering Applications: Load-cell and strain-gauge measurement in CNC and hydraulic press systems, proximity and displacement sensing in robotic cells, and signal conditioning and noise reduction for vibration sensors on automotive test benches.

Module 3: Data Acquisition and Industrial Instrumentation Systems (9 Hours)

Data acquisition systems (DAQ), analog and digital instrumentation, A/D and D/A converters, industrial data logging, SCADA basics, PLC-integrated instrumentation systems, industrial displays, calibration procedures, fault diagnosis techniques.

Engineering Applications:DAQ-based data logging for machine-tool testing, PLC-integrated instrumentation in quality-control stations, and SCADA-based plant monitoring with calibration and fault diagnosis of measurement loops.

Module 4: Industrial Communication and Automation (9 Hours)

Industrial communication protocols, Modbus, CAN bus, PROFIBUS, Industrial Ethernet, IoT-enabled instrumentation, wireless sensor networks, HMI systems, industrial automation architecture, smart factory concepts.

Engineering Applications: Modbus/PROFIBUS-connected sensors on automated production lines, CAN-bus instrumentation in automotive systems, and IoT-enabled wireless sensor networks with HMI panels for smart factory monitoring.

Module 5: Intelligent Monitoring and Predictive Maintenance (9 Hours)

AI-enabled smart sensors, predictive maintenance concepts, machine health monitoring, vibration analysis, thermal monitoring, intelligent fault detection, cloud-based monitoring systems, industrial analytics, mini-project implementation.

Engineering Applications: Vibration- and thermal-monitoring-based predictive maintenance of pumps, motors, and CNC spindles; AI-based fault detection in production equipment; cloud-based machine health dashboards.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	–	1	–	1	–	–	–	–	–	–	–	–
CO2	3	–	1	–	1	–	–	–	–	–	–	–	–
CO3	2	3	–	2	1	–	–	–	–	–	–	–	–
CO4	1	–	–	–	1	–	–	–	–	2	–	–	–
CO5	2	3	–	–	2	–	–	–	–	–	–	–	–

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

- AI-assisted sensor calibration and intelligent signal filtering techniques.
- Smart diagnostics using AI-enabled industrial sensing systems.
- AI-enabled industrial data acquisition and fault prediction systems.
- Intelligent industrial monitoring using data analytics.
- Machine learning-based predictive maintenance systems.
- AI-assisted condition monitoring and industrial analytics.
- Students critically evaluate sensor performance and industrial measurement accuracy under varying operating conditions.
- Students compare conventional and intelligent instrumentation systems for industrial reliability and efficiency.
- Students analyze ethical, operational, and industrial implications of AI-assisted automation and predictive maintenance systems.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Bosch Rexroth Industrial Automation Kits
- PLC and SCADA Systems
- LabVIEW
- MATLAB
- Industrial DAQ Systems
- Arduino / Raspberry Pi

Suggested Reading

Reference Books

- H.S. Kalsi, Electronic Instrumentation, McGraw Hill.
- Bela G. Liptak, Instrument Engineers' Handbook, CRC Press.
- Ernest O. Doebelin, Measurement Systems: Application and Design, McGraw Hill.

Additional Resources

- Bosch Rexroth Learning Portal
- NPTEL: Smart Sensors and Industrial Instrumentation – IIT Kharagpur
- IEEE Sensors Journal – Research Papers on Smart Sensing Systems
- NPTEL: Industrial Automation and Control

DLI Course Mapped

Fundamentals of Deep Learning for Sensor Data Analytics
https://learn.nvidia.com/

DLI Learning Path

- AI for Smart Sensing and Instrumentation
- Industrial IoT and Sensor Networks
- Predictive Analytics using Sensor Data

Hydraulic and Pneumatic System Engineering

(As per Choice Based Credit System)	
Course Code: 26MDE5111	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Fluid Mechanics, Applied Thermodynamics, Machine Design, Industrial Automation, Basic Control Systems	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop advanced competence in the design, modelling, simulation, control, operation, and maintenance of hydraulic and pneumatic systems used in modern mechanical, manufacturing, automation, aerospace, mobile, and process industries. The course enables M.Tech students to analyse fluid power components and circuits, integrate electro-hydraulic/electro-pneumatic control with PLC and sensors, and apply AI-assisted diagnostics, energy-efficient design, predictive maintenance, and responsible engineering judgement for high-performance fluid power systems.

Course Objectives

Students will be able to:

- Gain advanced knowledge of hydraulic and pneumatic power transmission principles, fluid properties, symbols, safety standards, and industrial applications.
- Analyse pumps, compressors, valves, actuators, accumulators, FRL units, sensors, and control components based on pressure, flow, force, speed, power, efficiency, and dynamic response.
- Design and simulate hydraulic, pneumatic, electro-hydraulic, and electro-pneumatic circuits for sequencing, speed control, force control, automation, and safety interlocking.
- Apply proportional, servo, PLC-based, and sensor-feedback control strategies for fluid power systems using simulation and laboratory platforms.
- Evaluate system performance, fault behaviour, leakage, energy consumption, reliability, maintainability, predictive diagnostics, and sustainability using AI-assisted and engineering-validated approaches.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the fundamental laws, symbols, safety practices, and performance parameters of hydraulic and pneumatic systems.	L2
CO2	Apply hydraulic components, circuits, and system-design principles to determine pressure, flow, force, speed, power, and efficiency of hydraulic systems.	L3
CO3	Develop and simulate pneumatic and electro-pneumatic circuits and analyze their operating characteristics for industrial automation applications.	L4
CO4	Apply proportional, servo, and PLC-based control techniques with sensor feedback to fluid power systems using modelling and simulation.	L3
CO5	Analyze faults, energy efficiency, and sustainability aspects of fluid power systems and develop AI-assisted, human-validated predictive maintenance solutions.	L4

Broad Course Description

Hydraulic and Pneumatic System Engineering is an advanced M.Tech course focused on the generation, transmission, control, automation, and optimization of power using pressurized liquids and compressed air. The course begins with fluid power fundamentals, pressure-flow-force relationships, ISO symbols, safety practices, and component-level performance analysis. Students study hydraulic power packs, pumps, reservoirs, filters, cylinders, motors, accumulators, valves, compressors, FRL units, pneumatic actuators, and electro-fluidic control elements from an engineering design perspective.

The course progresses to circuit design and system-level integration, including speed-control circuits, pressure-control circuits, regenerative circuits, sequencing circuits, load-holding circuits, electro-pneumatic control, PLC-based actuator sequencing, proportional and servo-hydraulic systems, and sensor-based feedback control. Emphasis is placed on modelling, simulation, laboratory validation,

troubleshooting, energy efficiency, leakage reduction, predictive maintenance, and Industry 4.0-enabled smart fluid power systems.

The course integrates AI-assisted learning and Authentic Intelligence reflection. Students use AI tools for circuit generation, component selection, fault-tree preparation, data interpretation, predictive diagnostics, and report writing, while validating all AI outputs through equations, datasheets, safety standards, simulation, and laboratory observations. The course prepares postgraduate students for advanced roles in automation, manufacturing, mobile hydraulics, robotics, aerospace systems, machine tools, industrial maintenance, and smart factory engineering.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Fluid Power Systems and Safety (6 Hours)

Introduction to fluid power engineering; comparison of mechanical, electrical, hydraulic, and pneumatic power transmission; Pascal's law; pressure, flow, force, speed, power, efficiency, and compressibility; hydraulic fluids and compressed-air properties; ISO symbols and circuit representation; fluid contamination, filtration, leakage, cavitation, aeration, noise, heat generation, and safe operation; safety standards, lockout/tagout awareness, and laboratory practices.

Engineering Applications: Hydraulic presses, lifting platforms, clamping fixtures, packaging systems, machine tools, robotic grippers, aircraft ground-support equipment, and automated manufacturing cells.

Module 2: Hydraulic Components, Circuits and System Design (6 Hours)

Hydraulic power units; reservoirs, pumps, filters, coolers, accumulators, hoses, fittings, seals, pressure gauges, flow meters, and sensors; hydraulic actuators: single-acting and double-acting cylinders, rotary actuators, and motors; direction control valves, pressure control valves, flow control valves, check valves, counterbalance valves, sequence valves, and pressure-compensated valves; actuator sizing, pump sizing, pressure drop, heat-load estimation, speed control, meter-in, meter-out, bleed-off, regenerative, sequencing, and load-holding circuits.

Engineering Applications: Hydraulic presses, injection-moulding machines, CNC clamping systems, mobile equipment, lifting tables, forming machines, and heavy-duty industrial automation.

Module 3: Pneumatic and Electro-Pneumatic System Engineering (6 Hours)

Compressed air generation, compressors, receivers, dryers, filters, regulators, lubricators, distribution lines, leakage and pressure drop; pneumatic actuators, cylinders, rotary actuators, grippers, vacuum systems, and air motors; 3/2, 5/2, and 5/3 directional control valves; flow control, quick exhaust, time-delay, shuttle, twin-pressure, and logic valves; pneumatic sequencing, cascade method, electro-pneumatic valves, solenoids, relays, sensors, timers, counters, and basic PLC logic for pneumatic automation.

Engineering Applications: Pick-and-place systems, packaging machines, stamping units, sorting stations, assembly lines, robotic grippers, fixture automation, and low-force manufacturing automation.

Module 4: Proportional, Servo and PLC-Based Fluid Power Control (6 Hours)

Electro-hydraulic and electro-pneumatic control architecture; solenoid-operated, proportional, and servo valves; valve characteristics, deadband, hysteresis, frequency response, and spool dynamics; closed-loop position, velocity, force, and pressure control; feedback sensors: pressure, flow, displacement, velocity, and force sensors; PID control, stability issues, basic modelling of hydraulic actuators and pneumatic systems; PLC interfacing, ladder logic for fluid power sequencing, interlocks, emergency-stop logic, HMI/SCADA visualization, and data acquisition.

Engineering Applications: Servo-hydraulic testing machines, robotic actuation, motion-control platforms, automated presses, proportional pressure control, smart pneumatic stations, and PLC-controlled manufacturing cells.

Module 5: Fault Diagnosis, Energy Efficiency, Smart Fluid Power and Sustainability (6 Hours)

Common hydraulic and pneumatic faults: leakage, actuator drift, low pressure, slow response, cavitation, overheating, contamination, air entrainment, valve sticking, seal failure, compressor inefficiency, and pressure losses; systematic troubleshooting and fault-tree analysis; preventive and predictive maintenance; condition monitoring using pressure, flow, temperature, vibration, and position data; compressed-air energy audit, leakage reduction, pressure optimization, load-sensing systems, variable-speed drives, digital twins, IIoT dashboards, cybersecurity basics, lifecycle cost, environmental considerations, and sustainable fluid power design.

Engineering Applications: Predictive maintenance of pumps, compressors, actuators and valves, energy-efficient factory automation, smart hydraulic power units, digital maintenance dashboards, and Industry 4.0-enabled fluid power systems.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	–	1	–	1	2	–	–	–	–	–	–	2
CO2	2	3	–	–	1	–	–	–	–	–	–	–	3
CO3	2	–	3	–	1	–	–	–	–	–	–	2	3
CO4	2	2	–	2	3	–	–	–	–	–	–	–	3
CO5	2	3	3	2	3	–	3	–	–	–	–	–	3

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand how AI-assisted diagnostics, predictive maintenance, and simulation tools improve the design, control, and reliability of hydraulic and pneumatic systems.

Example Activities:

- Use AI-assisted tools to analyse sensor data (pressure, flow, temperature) for fault detection in a hydraulic circuit.
- Simulate a proportional or servo-controlled fluid power circuit and compare AI-predicted response with analytical results.
- Develop a predictive maintenance model for a pump or compressor using historical operating data.
- Evaluate energy efficiency improvements suggested by AI-based analysis of a compressed-air system.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across

the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Simulation: FluidSIM, Automation Studio, MATLAB/Simulink, Simscape Fluids, AMESim, LabVIEW, or equivalent fluid power simulation platforms.
- Laboratory Hardware: Hydraulic and pneumatic trainers, electro-pneumatic/electro-hydraulic rigs, proportional/servo valve kits, PLC panels, sensors, pressure gauges, flow meters, compressors, and power packs.
- Automation & Data Tools: PLC programming software, HMI/SCADA tools, Node-RED, Excel/Power BI dashboards, OPC UA/MQTT-based data acquisition tools.
- AI-Assisted Engineering Tools: ChatGPT or equivalent AI assistants, engineering calculation tools, spreadsheet AI tools, Python/Jupyter notebooks for data analysis and fault detection.

Suggested Reading

Primary Textbooks

- Anthony Esposito, Fluid Power with Applications, Pearson.
- S. R. Majumdar, Oil Hydraulic Systems: Principles and Maintenance, Tata McGraw-Hill.
- S. R. Majumdar, Pneumatic Systems: Principles and Maintenance, Tata McGraw-Hill.
- Andrew Parr, Hydraulics and Pneumatics: A Technician's and Engineer's Guide, Butterworth-Heinemann.

Reference Books

- Herbert E. Merritt, Hydraulic Control Systems, John Wiley & Sons.
- John Watton, Fundamentals of Fluid Power Control, Cambridge University Press.
- D. A. Pease and J. J. Pippenger, Basic Fluid Power, Pearson / Prentice Hall.
- W. Bolton, Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering, Pearson.
- Frank D. Petruzella, Programmable Logic Controllers, McGraw-Hill.

Additional Resources

- NPTEL / SWAYAM courses on Oil Hydraulics and Pneumatics, Fluid Power Control, Industrial Automation, and Mechatronics.
- Bosch Rexroth, Festo, Parker, Eaton, and SMC technical manuals, datasheets, and training resources.
- ISO 1219 fluid power graphical symbols, ISO 4413 hydraulic safety guidelines, and ISO 4414 pneumatic safety guidelines.
- Recent journal/conference papers on smart fluid power, predictive maintenance, compressed-air energy efficiency, and AI-based fault diagnosis.

DLI Course Mapped

Fundamentals of Accelerated Computing for Industrial Automation
https://learn.nvidia.com/

DLI Learning Path

- AI for Industrial Fluid Power Systems
- Predictive Maintenance for Hydraulic and Pneumatic Systems
- Smart Automation and Industrial IoT

Lean Manufacturing and Smart Production Systems

(As per Choice Based Credit System)	
Course Code: 26MDE5112	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Fundamentals of Manufacturing Processes and Industrial Engineering	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course develops advanced knowledge in Lean Manufacturing principles, waste elimination strategies, smart production systems, and Industry 4.0 technologies to improve productivity, quality, sustainability, and operational excellence in modern manufacturing industries. Learners will acquire analytical and practical skills to design efficient manufacturing systems by integrating lean tools, digital technologies, industrial automation, data-driven decision-making, and intelligent production methodologies.

Course Objectives

Students will be able to:

- Understand the principles, philosophy, and tools of Lean Manufacturing for eliminating waste and improving productivity.
- Apply lean production techniques such as Value Stream Mapping, Kaizen, 5S, JIT, Kanban, and TPM in industrial environments.
- Analyze smart manufacturing technologies including IoT, Cyber Physical Systems, Digital Twins, and AI-driven production systems.
- Evaluate manufacturing system performance using data analytics, automation, and intelligent production monitoring techniques.
- Develop sustainable and intelligent production strategies integrating lean concepts with Industry 4.0 technologies

Course Outcomes (CO)

CO	Course Outcome	BTL

CO	Course Outcome	BTL
CO1	Explain lean production principles and tools, including value stream mapping, Kaizen, cellular manufacturing, Kanban, and Just-In-Time, for waste reduction and process optimization.	L2
CO2	Analyze equipment and maintenance performance using Total Productive Maintenance, OEE, and reliability-centered maintenance, and identify sustainable manufacturing improvements.	L4
CO3	Analyze Industry 4.0 technologies, including IoT, cyber-physical systems, cloud manufacturing, edge computing, and digital twins, for smart manufacturing applications.	L4
CO4	Apply integrated lean–Industry 4.0 frameworks, production analytics, and simulation to improve the performance of smart lean factories.	L3
CO5	Analyze smart production systems, digital dashboards, cybersecurity issues, and workforce transformation challenges using lean-transformation case studies.	L4

Broad Course Description

This course introduces advanced concepts of Lean Manufacturing and Smart Production systems used in modern industries to enhance operational efficiency, productivity, quality, and sustainability. The course emphasizes elimination of waste, optimization of resources, continuous improvement culture, and integration of digital manufacturing technologies.

Learners will explore fundamental lean concepts including Value Stream Mapping (VSM), Kaizen, Kanban, 5S, Just-In-Time (JIT), Cellular Manufacturing, Single Minute Exchange of Dies (SMED), and Total Productive Maintenance (TPM). The course further extends into Smart Manufacturing technologies such as Industrial Internet of Things (IIoT), Artificial Intelligence (AI), Machine Learning (ML), Cyber Physical Systems (CPS), cloud manufacturing, digital twins, big data analytics, and intelligent automation.

The course enables students to understand how lean methodologies and Industry 4.0 technologies together create responsive, flexible, sustainable, and intelligent production environments. Through industrial case studies, analytical tools, simulation concepts, and smart manufacturing applications, students gain the capability to transform conventional production systems into digitally enabled smart factories.

Detailed Course Syllabus

Course Modules

Module 1: Lean Production Tools and Process Optimization (9 Hours)

Value Stream Mapping (Current state and future state mapping). Process flow analysis. Bottleneck identification and process balancing. Kaizen methodology and continuous improvement events. Cellular manufacturing systems. Group technology concepts. Kanban systems and pull production mechanisms. Just-In-Time (JIT) manufacturing principles. Heijunka and production leveling. Takt time calculation and cycle time optimization. Single Minute Exchange of Dies (SMED). Setup time reduction techniques. Lean supply chain concepts. Inventory reduction and warehouse optimization. Material flow optimizations

Engineering Applications: *Flexible manufacturing systems, Assembly line balancing, Warehouse and logistics optimization, Precision manufacturing industries*

Module 2: Total Productive Maintenance and Sustainable Manufacturing (9 Hours)

Introduction to Total Productive Maintenance (TPM): Equipment reliability and maintainability, Overall Equipment Effectiveness (OEE), autonomous maintenance, planned maintenance, and downtime reduction strategies. Overview of predictive, condition-based, and Reliability-Centered Maintenance (RCM). Sustainable manufacturing concepts: Green manufacturing and energy-efficient production, resource optimization, circular economy concepts, and integration of lean and sustainable manufacturing. Sustainable production metrics: Energy monitoring and carbon footprint reduction strategies.

Engineering Applications: *CNC machine maintenance systems, Smart energy management in industries, Sustainable automotive manufacturing, Renewable energy component production.*

Module 3: Smart Manufacturing and Industry 4.0 Technologies (9 Hours)

Introduction to Industry 4.0: Smart factories, digital transformation, Cyber Physical Systems (CPS), and Industrial Internet of Things (IIoT). Smart sensors and actuators, data acquisition, and machine connectivity. Cloud manufacturing and edge computing in manufacturing. Digital Twin technology and virtual production systems. AI/ML and big data analytics for production optimization and smart quality control. Robotics and collaborative robots (cobots) and human-machine interaction. Real-time production monitoring systems and Manufacturing Execution Systems (MES).

Engineering Applications: *Smart assembly lines, AI-based quality inspection systems, Predictive maintenance using IoT, Autonomous production systems*

Module 4: Integrated Lean (9 Hours)

Integration of Lean Manufacturing with Smart Production systems. Lean Industry 4.0 framework. Intelligent decision-making systems in manufacturing. Smart lean factories and digital lean implementation. Production analytics and performance optimization. Simulation and optimization of manufacturing systems.

Engineering Applications: *Lean–Industry 4.0 implementation on an automotive assembly line, production analytics for OEE improvement in machining cells, and simulation-based layout and scheduling optimization of smart lean factories.*

Module 5: Smart Production Systems (9 Hours)

Digital dashboards for production monitoring. Case studies on lean transformation and smart

manufacturing implementation. Challenges in digital transformation. Cybersecurity issues in smart factories. Workforce transformation and future manufacturing trends. Advanced concepts: Additive Manufacturing integration, autonomous production systems, AI-driven manufacturing optimization, and sustainable smart production ecosystems.

Engineering Applications: *Intelligent manufacturing plants, Semiconductor manufacturing systems, Smart aerospace manufacturing, Integrated digital production facilities*

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	–	–	–	2	–	–	–	–	–	–	1	2
CO2	1	–	–	–	3	–	–	–	–	–	–	–	–
CO3	2	3	2	–	2	–	–	–	–	–	–	2	3
CO4	2	2	1	–	2	–	–	–	–	–	–	2	3
CO5	2	–	3	–	2	–	3	–	–	–	–	2	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

Example: Develop an AI-assisted predictive maintenance framework for manufacturing equipment:

- Collect machine operational parameters such as vibration, temperature, and energy consumption.
- Analyze production data using machine learning concepts to identify abnormal operating conditions.
- Develop a predictive maintenance workflow to estimate machine failures before breakdown occurs.
- Create a smart production dashboard for monitoring equipment performance and maintenance schedules.
- Evaluate productivity improvement achieved using AI-based maintenance planning.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Lean Manufacturing Assessment Tools
- Manufacturing Simulation Software
- ERP and MES Platforms
- Digital Twin Simulation Tools
- IoT Development Platforms
- Data Analytics and Visualization Tools

Suggested Reading

Reference Books

- Jeffrey K. Liker, “The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer”, McGraw Hill, 2nd Edition, 2021.

- Dennis P. Hobbs, "Lean Manufacturing Implementation: A Complete Execution Manual for Any Size Manufacturer", J. Ross Publishing, 2004 Edition.
- Frank Lamb, "Industrial Automation: Hands On", McGraw Hill Education, 1st Edition, 2013.
- Alasdair Gilchrist, "Industry 4.0: The Industrial Internet of Things", Apress, 1st Edition, 2016.
- Klaus Schwab, "The Fourth Industrial Revolution", Crown Business, 2017 Edition.

Additional Resources

- NPTEL: Lean Manufacturing Systems
- NPTEL: Industry 4.0 and Industrial Internet of Things
- MIT OpenCourseWare – Manufacturing Systems
- SME Smart Manufacturing Resource Center

DLI Course Mapped

Smart Manufacturing and Digital Transformation
https://learn.nvidia.com/

DLI Learning Path

- Smart Production and Industry 4.0
- AI for Lean Manufacturing Optimization
- Digital Transformation in Production Systems

Smart Materials and Adaptive Structural Systems

(As per Choice Based Credit System)	
Course Code: 26MDE5113	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mechanics, Mechanics of Materials, Strength of Materials.	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop an understanding of smart materials and adaptive structural systems used in modern engineering applications. It enables students to study materials that respond to mechanical, thermal, electrical, magnetic, optical, and environmental stimuli. The course emphasizes the use of piezoelectric materials, shape memory alloys, magnetostrictive materials, electroactive polymers, smart fluids, fiber optic sensors, and self-healing materials for sensing, actuation, vibration control, morphing structures, structural health monitoring, and intelligent product design.

Course Objectives

Students will be able to:

- Gain knowledge of smart materials, their response mechanisms, properties, and engineering relevance.
- Understand sensing and actuation principles using piezoelectric, shape memory, magnetostrictive, electroactive, and smart fluid-based materials.
- Analyze adaptive structural systems for vibration control, shape control, damage detection, and structural health monitoring.
- Apply smart materials in mechanical, aerospace, automotive, biomedical, civil, robotic, and energy systems.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the classification, properties, and working principles of smart	L2

CO	Course Outcome	BTL
	materials and adaptive systems.	
CO2	Apply the behavior of piezoelectric, pyroelectric, and fiber-optic smart materials to sensing, actuation, and vibration-control applications.	L3
CO3	Analyze the behavior of shape memory alloys, magnetostrictive materials, and electroactive polymers in actuation and sensing applications.	L4
CO4	Apply smart fluids, self-healing materials, and structural health monitoring concepts to semi-active control and self-monitoring systems.	L3
CO5	Analyze adaptive structural systems incorporating smart materials and AI-assisted control strategies for vibration control and shape adaptation.	L4

Broad Course Description

This course introduces smart materials and adaptive structural systems with emphasis on engineering design and practical applications. It covers the fundamental principles of stimulus-responsive materials, sensing and actuation mechanisms, piezoelectric materials, shape memory alloys, magnetostrictive materials, electroactive polymers, electrorheological and magnetorheological fluids, fiber optic sensors, self-healing materials, and multifunctional materials. The course further discusses adaptive structures, active vibration control, morphing structures, energy harvesting, structural health monitoring, and smart system integration. Students will learn how smart materials can be used to develop intelligent mechanical systems, aerospace structures, automotive components, biomedical devices, robotic systems, and condition-monitoring solutions.

Detailed Course Syllabus

Course Modules

Module 1: Introduction to Smart Materials and Adaptive Systems (9 Hours)

Definition and characteristics of smart materials, need for smart materials in modern engineering design, classification of smart materials, stimulus-response behavior, sensing and actuation concepts, active and passive smart systems, adaptive and intelligent structures, multifunctional materials, feedback-based structural systems, smart material selection criteria, comparison of conventional and smart materials, basic concepts of sensors, actuators, controllers, signal conditioning, response time, sensitivity, hysteresis, repeatability, reliability, durability, and system integration.

Engineering Applications: Smart aircraft wings, vibration-controlled machine tools, adaptive

automotive suspension, robotic grippers, biomedical implants, self-monitoring bridges, smart prosthetics, energy harvesters, morphing structures, and intelligent manufacturing systems.

Module 2: Piezoelectric, Pyroelectric and Fiber Optic Smart Systems (9 Hours)

Piezoelectric effect, direct and converse piezoelectric effect, piezoelectric constitutive relations, common piezoelectric materials, PZT ceramics, PVDF polymers, piezoelectric sensors and actuators, piezoelectric patches, bimorphs and stacks, piezoelectric vibration control, piezoelectric energy harvesting, pyroelectric materials and thermal sensing, fiber optic sensors, fiber Bragg grating sensors, strain and temperature measurement, embedded sensors in structures, signal interpretation, advantages and limitations of piezoelectric and fiber optic systems.

Engineering Applications: Vibration control of beams and plates, pressure sensors, accelerometers, ultrasonic transducers, precision positioning systems, energy harvesting from machinery vibration, structural health monitoring of composite panels, bridges, wind turbine blades, aerospace structures, and pipelines.

Module 3: Shape Memory Materials, Magnetostrictive Materials and Electroactive Polymers (9 Hours)

Shape memory effect, pseudoelasticity, one-way and two-way shape memory behavior, phase transformation in shape memory alloys, martensite and austenite phases, NiTi shape memory alloys, shape memory polymers, design parameters for SMA actuators, recovery stress, transformation temperature, hysteresis and fatigue of SMA, magnetostriction, magnetostrictive materials, Terfenol-D, magnetostrictive sensors and actuators, electroactive polymers, ionic and electronic EAPs, dielectric elastomers, artificial muscles, actuation strain, force output, response speed, durability and design limitations.

Engineering Applications: SMA-based actuators, self-deploying aerospace structures, biomedical stents, orthodontic wires, adaptive valves, robotic grippers, artificial muscles, active engine mounts, precision actuators, micro-positioning systems, morphing wings, adaptive mechanisms, and soft robotics.

Module 4: Smart Fluids, Self-Healing Materials and Structural Health Monitoring (9 Hours)

Electrorheological fluids, magnetorheological fluids, field-dependent viscosity, MR dampers, ER dampers, semi-active vibration control, smart fluid-based brakes and clutches, self-healing polymers, microcapsule-based healing, vascular self-healing systems, reversible bonding, self-healing composites, damage detection methods, structural health monitoring, sensor networks, guided waves, acoustic emission, vibration-based damage detection, impedance-based monitoring, condition monitoring, data acquisition systems, digital twins for structural monitoring.

Engineering Applications: MR dampers in vehicle suspension, earthquake-resistant structures, adaptive machine mounts, vibration isolators, smart helmets, self-healing coatings, aircraft damage monitoring, wind turbine blade monitoring, bridge health monitoring, composite structure inspection, and predictive maintenance systems.

Module 5: Adaptive Structural Systems, Control and AI-Assisted Design (9 Hours)

Adaptive structures: active, passive, and semi-active control; shape control and morphing structures; smart beams, plates, and composite laminates with integrated sensor-actuator systems. Control strategies for adaptive systems: feedback, feedforward, and PID control; basics of state-space representation, stability, and response analysis. Smart material-based design optimization and

reliability of adaptive systems. AI-assisted fault diagnosis and machine learning for structural health monitoring; digital twin-based adaptive systems.

Engineering Applications: Active vibration control of beams and machine structures, morphing aircraft wings, adaptive robotic arms, smart vehicle suspension, active noise control systems, precision manufacturing systems, smart prosthetic devices, adaptive building structures, intelligent aerospace panels, and AI-enabled predictive maintenance.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	–	–	–	2	–	–	–	–	–	–	–	2
CO2	1	–	1	–	1	–	–	–	–	–	–	–	2
CO3	2	3	1	–	1	–	–	–	–	–	–	–	3
CO4	2	3	3	–	1	–	3	–	–	–	–	2	3
CO5	2	–	3	–	3	–	–	–	–	–	–	2	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Understand how Artificial Intelligence and data-driven methods enable adaptive control, condition monitoring, and optimized design of smart material-based structural systems.

Example Activities:

- Develop a machine-learning model to predict the actuation response of a piezoelectric or shape-memory-alloy element from input voltage/temperature data.
- Simulate AI-assisted structural health monitoring using strain-gauge or sensor datasets from smart structures.
- Evaluate AI-based control strategies for vibration suppression in adaptive structures.
- Compare conventional PID control with AI-based adaptive control for a smart structural system.
- Analyse sensor-fusion techniques for real-time damage detection in smart composite structures.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%,

covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Analytical Calculation: Scientific calculator, Excel / Google Sheets
- Programming / Computation: MATLAB / Python / GNU Octave
- Simulation Tools: ANSYS / Abaqus / COMSOL Multiphysics / Simulink / SolidWorks Simulation
- / Fusion 360 Simulation
- Control and Signal Processing: MATLAB Control System Toolbox, Simulink, Python SciPy, NumPy, Matplotlib
- Design Documentation: MS Word / LaTeX / Google Docs

Suggested Reading

Primary Textbooks

- M. V. Gandhi and B. S. Thompson, Smart Materials and Structures, Chapman & Hall.

- A. V. Srinivasan and D. Michael McFarland, Smart Structures: Analysis and Design, Cambridge University Press.

Reference Books

- Gauenzi, Smart Structures, Wiley.
- Brian Culshaw, Smart Structures and Materials, Artech House.

Additional Resources

- NPTEL – Smart Materials and Structures
- NPTEL – Intelligent Materials and Structures
- NPTEL – Structural Health Monitoring
- MIT OpenCourseWare – Structural Mechanics and Dynamics
- ANSYS Innovation Courses – Structural Analysis and Vibration

DLI Course Mapped

Fundamentals of Accelerated Computing https://learn.nvidia.com/

DLI Learning Path

- Accelerated Computing
- AI-Assisted Adaptive Structural Control
- Smart Materials for Structural Health Monitoring

AI-Driven Structural Analysis and Mechanics

(As per Choice Based Credit System)	
Course Code: 26MDE5114	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Strength of Materials, Theory of elasticity, Finite Element Analysis, Basic Programming Knowledge	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to integrate artificial intelligence techniques with structural analysis and mechanics to solve advanced engineering problems. The course enables students to apply machine learning, optimization, data-driven modeling, and intelligent computational techniques for structural behavior prediction, failure analysis, and smart decision-making in mechanical systems.

Course Objectives

Students will be able to:

- Gain knowledge of advanced structural mechanics and AI-driven computational approaches for engineering analysis.
- Understand machine learning techniques for stress, deformation, vibration, and failure prediction.
- Apply AI-based optimization methods for structural design and integrity assessment.
- Develop intelligent models for condition monitoring, damage detection, and predictive maintenance.
- Analyze real-world structural datasets using AI tools and simulation-based learning approaches.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain machine learning techniques, including regression,	L2

CO	Course Outcome	BTL
	classification, neural networks, and decision trees, used to predict structural behavior such as stress, deformation, and fatigue life.	
CO2	Apply genetic algorithms, topology optimization, and surrogate modeling to AI-based structural optimization and intelligent design.	L3
CO3	Analyze structural sensor data using signal processing and AI-based anomaly detection for damage identification and predictive maintenance.	L4
CO4	Apply AI-assisted finite element simulation, hybrid physics-informed models, and explainable-AI techniques in structural simulation workflows.	L3
CO5	Analyze smart structural systems that integrate sensors, actuators, and AI-based controllers for real-time vibration and shape control.	L4

Broad Course Description

This course introduces the integration of artificial intelligence with structural analysis and mechanics for advanced engineering applications. The course covers intelligent computational approaches including machine learning, neural networks, optimization algorithms, predictive analytics, and AI-assisted finite element analysis. Students learn to analyze structural behavior, detect damage, optimize designs, and predict failures using data-driven approaches. Practical exposure is provided through AI-integrated simulation exercises and engineering case studies related to smart manufacturing, aerospace, automotive, and infrastructure systems.

Detailed Course Syllabus

Course Modules

Module 1: Machine Learning for Structural Behavior Prediction (9 Hours)

Structural response and failure fundamentals: stress, strain, deformation, and natural frequency as prediction targets; yielding, buckling, and fatigue failure modes; generation of training data from finite element analysis and experiments. Machine learning fundamentals, regression and classification techniques, neural networks, support vector machines, decision trees, feature extraction from structural datasets, prediction of stress, strain, deformation, fatigue life, and vibration characteristics using AI models.

Engineering Applications: Prediction of crack propagation in structures, vibration analysis of rotating systems, fatigue life estimation of automotive components.

Module 2: AI-Based Structural Optimization and Intelligent Design (9 Hours)

Optimization techniques in mechanics, genetic algorithms, particle swarm optimization, topology optimization, multi-objective optimization, AI-driven design exploration, integration of CAD/CAE with AI tools, surrogate modeling for structural analysis.

Engineering Applications: Lightweight structural design for aerospace applications, optimized truss structures, intelligent design of mechanical assemblies.

Module 3: Damage Detection, Structural Health Monitoring and Predictive Maintenance (9 Hours)

Structural health monitoring concepts, sensor-based monitoring systems, signal processing, AI for damage identification, anomaly detection techniques, predictive maintenance strategies, digital twin concepts, reliability and structural integrity assessment.

Engineering Applications: Bridge health monitoring systems, predictive maintenance in industrial machinery, AI-based crack detection in pressure vessels.

Module 4: AI-Integrated Simulation (9 Hours)

Review of the finite element structural analysis workflow (idealization, meshing, solution, post-processing) as the physics baseline for AI integration. AI-assisted finite element simulations, intelligent simulation workflows, hybrid physics-informed AI models, explainable AI in engineering mechanics, cloud-based simulation platforms, ethical considerations in AI-driven engineering.

Engineering Applications: Surrogate-assisted stress analysis of engine and chassis brackets, physics-informed neural network solutions for beam and plate deflection, and cloud-based parametric analysis of aerospace structures with explainable-AI review of design decisions.

Module 5: Smart Structural Systems (9 Hours)

Concepts of smart and adaptive structural systems, integration of sensors, actuators, and AI-based controllers for real-time structural response management, self-monitoring and self-adapting structural concepts, AI-enabled vibration and shape control strategies, data-driven decision-making for structural adaptation, and design considerations for intelligent structural systems.

Engineering Applications: Smart vibration control systems, adaptive aerospace structures, intelligent robotic structural systems, self-monitoring bridges and buildings.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	3	–	2	3	–	–	–	–	–	–	–	3
CO2	2	2	3	–	3	–	–	–	–	–	–	–	3
CO3	2	3	–	–	2	–	–	–	–	–	–	–	3
CO4	2	3	2	2	3	–	–	–	–	–	–	–	3

CO5	1	1	–	–	3	–	–	–	–	–	–	–	2

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand how Artificial Intelligence and machine learning methods can be integrated with structural analysis and mechanics to accelerate stress prediction, failure assessment, and design optimization.

Example Activities:

- Develop and train a neural-network surrogate model to predict stress distribution in a structural component from finite element training data.
- Apply AI-assisted topology optimization to a load-bearing bracket and compare with conventional optimization methods.
- Use machine-learning classifiers to predict failure mode (yielding, buckling, fatigue) from loading and geometric parameters.
- Evaluate the accuracy of physics-informed neural networks (PINNs) against classical analytical solutions for a beam/plate problem.
- Compare AI-assisted and conventional structural reliability assessment methods using a case study.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Programming & AI: Python, MATLAB
- Simulation Software: ANSYS, Abaqus, COMSOL Multiphysics
- Machine Learning Libraries: TensorFlow, Scikit-learn, Keras, PyTorch
- Data Visualization: Matplotlib, Plotly
- AI-Assisted Development Tools: GitHub Copilot, ChatGPT
- Structural Analysis Tools: HyperWorks, SolidWorks Simulation

Suggested Reading

Reference Books

- Ian Goodfellow, Yoshua Bengio and Aaron Courville, “Deep Learning”, MIT Press.
- Hinton E. and Owen D. R. J., “Finite Element Programming”, Academic Press.
- S. Rajasekaran and G. A. Vijayalakshmi Pai, “Neural Networks, Fuzzy Logic and Genetic Algorithms”, PHI.
- Bishop C. M., “Pattern Recognition and Machine Learning”, Springer.
- Ashby M. F., “Materials Selection in Mechanical Design”, Elsevier.

Additional Resources

- NPTEL Courses on AI and Structural Mechanics
- Coursera – Machine Learning for Engineering Applications
- MATLAB Onramp and AI Courses

- NVIDIA Deep Learning Institute Courses
- Python Official Documentation

DLI Course Mapped

AI for Predictive Maintenance [NVIDIA Deep Learning Institute](https://learn.nvidia.com/?utm_source=chatgpt.com)

DLI Learning Path

- Artificial Intelligence and Accelerated Computing for Engineering Applications
- AI-Assisted Structural Analysis
- Physics-Informed Neural Networks for Mechanics

Python Programming for Design Engineers

(As per Choice Based Credit System)	
Course Code: 26MDE5115	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Basic Engineering Mathematics, Computer Fundamentals	
Course Type: Skill Enhancement Course (SEC)	**Hours/Week:** 04 **Total Hours:** 60 Hrs – 60 Hrs (Practical) **Credits:** 02
L – T – P – J: 0 – 0 – 4 – 0	

Course Vision

This course aims to equip design engineers with practical programming skills using Python for engineering computation, data analysis, design automation, optimization, visualization, and intelligent engineering applications. The course emphasizes hands-on implementation of computational techniques widely used in modern product design, simulation, manufacturing, and Industry 4.0 environments.

Course Objectives

Students will be able to:

- Develop Python programs for engineering problem solving and computational analysis.
- Apply numerical and scientific computing techniques using Python libraries.
- Create engineering data visualization and reporting solutions.
- Automate design and engineering workflows using Python scripting.
- Develop AI-assisted computational tools for engineering applications.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Develop Python programs using fundamental programming constructs for engineering applications.	L3
CO2	Apply scientific computing techniques using NumPy and related libraries.	L3

CO	Course Outcome	BTL
CO3	Perform engineering data analysis and visualization using Python tools.	L4
CO4	Develop automation scripts for engineering design and simulation workflows.	L4
CO5	Create AI-assisted engineering computational solutions and mini projects.	L5

Broad Course Description

This Skill Enhancement Course focuses on practical Python programming applications for design and manufacturing engineers. The course covers programming fundamentals,

scientific computing, engineering data analysis, visualization, optimization, automation, and AI-assisted engineering applications.

Students will work on real-world engineering datasets, computational models, simulation workflows, optimization problems, and automation tasks relevant to product development, design validation, manufacturing analytics, and digital engineering.

The course is delivered through extensive laboratory exercises, industrial case studies, mini-projects, and engineering problem-solving assignments.

Detailed Laboratory / Practical Syllabus

Laboratory Experiments and Practical Activities

This Skill Enhancement Course is conducted entirely in the laboratory (L – T – P – J: 0 – 0 – 4 – 0) and has no theory lectures. The 60 practical hours are organised as fifteen four-hour laboratory sessions on Python programming for engineering computation, data analysis, design automation and AI-assisted prediction. Each session begins with a short demonstration and is followed by individual or small-group hands-on work; the procedure, results and inferences of every experiment are recorded in a laboratory record / digital portfolio.

Experiments 1–5 (initial skills), 6–10 (intermediate skills) and 11–15 (advanced skills and mini project) correspond to CAT–1, CAT–2 and CAT–3 of the Assessment Scheme respectively.

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
1	**Python Environment Setup and Engineering Calculator**	Install and configure Anaconda, Jupyter and Spyder; write scripts using variables, data types and operators for engineering calculations (stress, torque, power); develop a unit-conversion utility.	CO1	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
2	**Control Structures and Function-Based Engineering Programs**	Implement conditional statements, loops, functions and user-defined modules to build calculators for beam deflection, gear parameters and material selection.	CO1	4
3	**File Handling and Engineering Data Structures**	Read and write text, CSV and Excel files of tensile-test and sensor data using lists, dictionaries and tuples; generate a formatted results file.	CO1	4
4	**Matrix Operations and Linear Systems using NumPy**	Perform array and matrix operations; solve simultaneous equations for truss and spring–mass systems; compute eigenvalues and mode shapes of a simple vibrating system.	CO2	4
5	**Root Finding, Differentiation and Integration using SciPy**	Solve nonlinear engineering equations (Newton–Raphson, Brent); apply numerical differentiation and trapezoidal/Simpson integration to load–deflection data.	CO2	4
6	**Curve Fitting and Interpolation of Experimental Data**	Fit polynomial and least-squares models and apply spline interpolation to stress–strain data; estimate Young's modulus and yield strength and report the fitting error.	CO2	4
7	**Engineering Dataset Processing using Pandas**	Import, clean, filter, group and merge manufacturing and material datasets; handle missing values and outliers; export the processed data.	CO3	4
8	**Statistical Analysis of Experimental Data**	Compute descriptive statistics, correlation and regression; construct histograms, frequency plots and control charts for statistical quality analysis.	CO3	4
9	**Scientific Visualization using Matplotlib and Seaborn**	Prepare publication-quality figures: stress–strain and S–N curves, contour and 3D surface plots, multi-panel layouts.	CO3	4
10	**Engineering Dashboard and Automated Report Generation**	Build an interactive dashboard for manufacturing/process data and auto-generate a formatted design report from the analysis results.	CO3	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
11	**Design Automation Scripting for Parametric Calculations**	Automate parametric design calculations for shafts and gears; run design-variation studies and export the results to CSV/Excel.	CO4	4
12	**CAD/CAE Workflow Automation using Python APIs**	Drive a CAD model through its Python API—modify parameters, regenerate geometry and export STEP/STL files—and batch-process multiple engineering files.	CO4	4
13	**Design Optimization using SciPy**	Formulate and solve constrained optimization problems (minimum-weight bracket or shaft design) using scipy.optimize and plot the design-space results.	CO4	4
14	**Machine Learning Model for Engineering Prediction**	Preprocess a material/process dataset, train regression models in scikit-learn, evaluate accuracy (R^2, RMSE) and interpret the predictions against engineering principles.	CO5	4
15	**Mini Computational Engineering Project**	Integrate data analysis, numerical computation, automation and prediction in a team mini project; submit the code, dashboard and report and give a demonstration.	CO5	4
Total Practical Hours				**60**

Laboratory Resources: Software, Tools and Equipment

- Anaconda Distribution
- JupyterLab / Jupyter Notebook with Spyder or VS Code
- NumPy, SciPy and Pandas libraries
- Matplotlib, Seaborn and Plotly for visualisation and dashboards
- scikit-learn for machine learning
- Autodesk Fusion 360 / Inventor Python API for CAD automation
- Engineering datasets (tensile-test, sensor and manufacturing process data)

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	3	–	3	–	–	–	–	–	–	–	–

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

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

Understand the application of Artificial Intelligence and Machine Learning techniques in solving engineering design and manufacturing problems using Python.

Example Activity:

Develop a machine learning model to predict the mechanical performance of engineering materials.

- Import and preprocess engineering datasets.
- Identify key design variables.
- Train machine learning algorithms using Python.
- Evaluate prediction accuracy.
- Interpret engineering significance of AI-generated results.

Students shall:

- Critically evaluate AI-generated predictions against engineering principles.
- Compare computational results with experimental observations.
- Analyze the limitations of machine learning models.
- Validate engineering decisions using domain knowledge.
- Reflect on ethical and responsible use of AI in engineering design.

Assessment Scheme

Skill Enhancement Course (Practical)

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Experiments 1–5	CO1 / CO2 (L1–L2)	20	Fundamental understanding. Quiz / Demonstration / Assignment / Concept Test / Viva
CAT–2 – Apply	Experiments 6–10	CO2 / CO3 (L2–L3)	20	Application of skills. Hands-on Task / Practical Exercise / Problem Solving / Software Activity / Lab Task
CAT–3 – Analyze / Create	Experiments 11–15	CO3 / CO4 / CO5 (L3–	20	Analysis, creation and application. Mini Project / Case Study / Design Task /

		L6)		Practical Demonstration / Presentation
Continuous Skill Assessment	Entire Course	As applicable	20	Practical Performance / Technical Assignment / Activity
Final Skill Demonstration	Entire Course	As applicable	20	Practical Demonstration / Viva / Project Presentation
Total CIA			**100**	**No SEE**

Suggested Reading

Reference Books

- John V. Guttag, Introduction to Computation and Programming Using Python, MIT Press.
- Steven C. Chapra, Applied Numerical Methods with MATLAB and Python, McGraw Hill.
- Jake VanderPlas, Python Data Science Handbook, O'Reilly Media.

Additional Resources

- Python Official Documentation
- NumPy Documentation
- SciPy Documentation
- Pandas Documentation
- NPTEL – Python for Data Science

DLI Course Mapped

Fundamentals of Deep Learning https://learn.nvidia.com/

DLI Learning Path

- Fundamentals of Deep Learning
- Data Science with Python
- Machine Learning for Engineering Applications
- AI for Manufacturing and Design

Engineering Simulation using ANSA

(As per Choice Based Credit System)	
Course Code: 26MDE5116	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mechanics, Finite Element Analysis, CAD Modeling Basics	
Course Type: Skill Enhancement Course (SEC)	**Hours/Week:** 04 **Total Hours:** 60 Hrs – 60 Hrs (Practical) **Credits:** 02
L – T – P – J: 0 – 0 – 4 – 0	

Course Vision

This course aims to develop industry-ready skills in Computer-Aided Engineering (CAE) model preparation using ANSA by enabling students to perform geometry cleanup, meshing, quality improvement, model validation, and solver deck generation for real-world engineering simulation applications in automotive, aerospace, manufacturing, and product development industries.

Course Objectives

Students will be able to:

- Understand the CAE pre-processing workflow used in industrial simulation projects.
- Perform geometry cleanup and defeaturing of CAD models for simulation readiness.
- Generate high-quality 2D and 3D meshes using ANSA.
- Apply quality criteria and mesh optimization techniques.
- Prepare complete simulation models and solver decks for structural, crash, and durability analyses.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Prepare CAD geometry for finite element analysis using ANSA tools.	L3
CO2	Generate high-quality shell meshes for engineering components.	L3
CO3	Develop solid meshing models for complex engineering applications.	L4

CO	Course Outcome	BTL
CO4	Apply mesh quality improvement and model validation techniques.	L4
CO5	Create complete simulation-ready models and solver decks for industrial CAE applications.	L5

Broad Course Description

This Skill Enhancement Course focuses on practical finite element model preparation using ANSA, one of the most widely adopted pre-processing platforms in the automotive, aerospace, heavy engineering, and manufacturing sectors.

The course provides extensive hands-on experience in geometry cleanup, midsurface extraction, shell meshing, tetra meshing, hexa meshing, quality improvement, connection modeling, assembly preparation, and solver deck generation.

Students will work on industrial CAD models commonly used in BIW structures, chassis systems, powertrain components, aerospace structures, pressure vessels, and mechanical assemblies.

The course is delivered through laboratory exercises, industrial case studies, CAE projects, and simulation model development assignments.

Detailed Laboratory / Practical Syllabus

Laboratory Experiments and Practical Activities

This Skill Enhancement Course is conducted entirely in the laboratory (L – T – P – J: 0 – 0 – 4 – 0) and has no theory lectures. The 60 practical hours are organised as fifteen four-hour laboratory sessions on CAE model preparation using ANSA. Each session begins with a short demonstration and is followed by individual or small-group hands-on work; the procedure, results and inferences of every experiment are recorded in a laboratory record / digital portfolio.

Experiments 1–5 (initial skills), 6–10 (intermediate skills) and 11–15 (advanced skills and mini project) correspond to CAT–1, CAT–2 and CAT–3 of the Assessment Scheme respectively.

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
1	**ANSA Interface, Database and CAD Import/Export**	Explore the ANSA interface and database structure; import and export CAD geometry (STEP/IGES); manage parts, properties and model organisation.	CO1	4
2	**Geometry Diagnostics and Topology Cleanup**	Run geometry checks; fix cracks, overlaps and duplicate surfaces; correct the topology of an automotive bracket.	CO1	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
3	**Defeaturing and Surface Repair**	Suppress holes, remove fillets and small features and repair surfaces of a sheet-metal component for simulation readiness.	CO1	4
4	**Mid-Surface Extraction and Shell Property Assignment**	Extract mid-surfaces from thin-walled solids; assign thickness, material and shell properties.	CO2	4
5	**2D Meshing of Sheet-Metal Components**	Generate shell meshes (automatic and manual) on brackets and automotive sheet-metal parts using defined element size and meshing parameters.	CO2	4
6	**Shell Meshing of Structural Frames and Assemblies**	Mesh a structural frame/assembly to quality criteria; reconstruct and optimize the mesh.	CO2	4
7	**Tetra Meshing of Solid Components**	Generate volume (tetra) meshes of mechanical components with size control and local refinement.	CO3	4
8	**Hexa and Sweep Meshing**	Create hexahedral meshes of prismatic and revolved components using sweep and block-based methods.	CO3	4
9	**Solid Mesh Validation and Feature Capture**	Validate volume meshes; apply feature capture and local refinement at fillets and holes.	CO3	4
10	**Meshing of an Industrial Component**	Mesh a powertrain/chassis component using a mixed shell–solid strategy and document the meshing approach.	CO3	4
11	**Mesh Quality Criteria and Error Identification**	Define quality criteria (aspect ratio, skewness, warpage, Jacobian, minimum and maximum angle) and identify failed elements.	CO4	4
12	**Mesh Quality Improvement and Batch Meshing**	Improve mesh quality using automatic and manual correction; run batch meshing on a set of parts.	CO4	4
13	**Model Checks and Validation**	Perform model checks (free edges, duplicate or penetrating elements, connectivity, mass and centre of gravity) for solver readiness.	CO4	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
14	**Connections, Assembly Preparation and Boundary Conditions**	Model spot welds, bolts and connectors; define contacts, loads and boundary conditions on an automotive subsystem assembly.	CO5	4
15	**Industrial CAE Mini Project and Solver Deck Generation**	Prepare a complete simulation-ready model of a BIW/chassis/aerospace sub-assembly; generate solver decks (NASTRAN/ABAQUS/LS-DYNA/OptiStruct) and review results in META.	CO5	4
Total Practical Hours				**60**

Laboratory Resources: Software, Tools and Equipment

- ANSA pre-processor
- META Post Processor
- Solver interfaces: NASTRAN, OptiStruct, ABAQUS and LS-DYNA
- Industrial CAD models (BIW, chassis, powertrain and aerospace components)
- ANSA Python scripting for batch meshing and automation

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	3	–	–	3	–	–	–	–	–	–	3	3
CO2	2	–	–	–	3	–	–	–	–	–	–	–	–
CO3	2	–	3	–	3	–	–	–	–	–	–	–	–
CO4	1	–	–	2	3	–	–	–	–	–	–	–	–
CO5	2	1	3	–	3	–	–	–	–	–	–	–	–

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

Understand AI-assisted CAE model preparation and intelligent mesh generation workflows used in modern simulation-driven product development.

Example Activity:

Develop an AI-assisted meshing workflow for an automotive structural component.

- Import and clean CAD geometry.
- Generate baseline mesh.

- Apply AI-assisted mesh quality recommendations.
- Compare conventional and AI-assisted meshing approaches.
- Evaluate computational efficiency and simulation accuracy.

Students shall:

- Critically assess AI-generated mesh recommendations.
- Validate simulation models using engineering judgment.
- Compare automated and manual meshing strategies.
- Analyze limitations of AI-assisted CAE workflows.
- Reflect on the role of engineers in simulation-driven product development.

Assessment Scheme

Skill Enhancement Course (Practical)

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Experiments 1–5	CO1 / CO2 (L1–L2)	20	Fundamental understanding. Quiz / Demonstration / Assignment / Concept Test / Viva
CAT–2 – Apply	Experiments 6–10	CO2 / CO3 (L2–L3)	20	Application of skills. Hands-on Task / Practical Exercise / Problem Solving / Software Activity / Lab Task
CAT–3 – Analyze / Create	Experiments 11–15	CO3 / CO4 / CO5 (L3–L6)	20	Analysis, creation and application. Mini Project / Case Study / Design Task / Practical Demonstration / Presentation
Continuous Skill Assessment	Entire Course	As applicable	20	Practical Performance / Technical Assignment / Activity
Final Skill Demonstration	Entire Course	As applicable	20	Practical Demonstration / Viva / Project Presentation
Total CIA			**100**	**No SEE**

Suggested Reading

Reference Books

- J.N. Reddy, Introduction to Finite Element Method, McGraw Hill.
- Saeed Moaveni, Finite Element Analysis: Theory and Application with ANSYS, Pearson.
- Robert Cook, Concepts and Applications of Finite Element Analysis, Wiley.

Additional Resources

- BETA CAE Systems Learning Portal
- ANSA Official Documentation
- META Post Processing Tutorials
- Automotive CAE Industry Case Studies
- NPTEL – Finite Element Analysis

DLI Course Mapped

Fundamentals of Accelerated Computing for CAE
https://learn.nvidia.com/

DLI Learning Path

- AI for Engineering Simulations
- Physics-Informed Machine Learning
- Accelerated Computing for CAE
- Digital Twin Development

Digital Product Design using Autodesk Inventor/Fusion 360

(As per Choice Based Credit System)	
Course Code: 26MDE5117	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Graphics, CAD Modeling Basics	
Course Type: Skill Enhancement Course (SEC)	**Hours/Week:** 04 **Total Hours:** 60 Hrs – 60 Hrs (Practical) **Credits:** 02
L – T – P – J: 0 – 0 – 4 – 0	

Course Vision

This course aims to develop industry-ready practical skills in digital product design using Autodesk Inventor and Fusion 360 through intensive hands-on modeling, assembly creation, simulation, rendering, and digital prototyping exercises for modern engineering applications.

Course Objectives

Students will be able to:

- Develop parametric 3D models using Autodesk Inventor and Fusion 360.
- Create complex assemblies and digital prototypes for engineering applications.
- Generate engineering drawings, rendering, and animations for product visualization.
- Apply simulation and validation tools for product performance analysis.
- Build industry-oriented digital product development workflows using cloud collaboration and generative design tools.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Develop parametric part models using Autodesk Inventor/Fusion 360 tools.	L3
CO2	Create assembly models and digital prototypes for mechanical	L3

CO	Course Outcome	BTL
	systems.	
CO3	Apply rendering, animation, and visualization techniques for product presentation.	L3
CO4	Generate engineering drawings and perform basic product validation simulations.	L4
CO5	Develop collaborative and AI-assisted digital product design workflows.	L5

Broad Course Description

This Skill Enhancement Course focuses entirely on practical digital product design workflows using Autodesk Inventor and Fusion 360. The course emphasizes extensive hands-on exercises covering part modeling, assembly design, sheet metal development,

simulation, rendering, additive manufacturing preparation, and collaborative product development.

Students will work on real-world industrial product modeling exercises commonly used in automotive, aerospace, machine design, tooling, consumer products, and smart manufacturing industries.

The course is designed as a studio-based practical learning environment with continuous CAD practice, mini projects, industrial design exercises, and digital prototyping assignments.

Detailed Laboratory / Practical Syllabus

Laboratory Experiments and Practical Activities

This Skill Enhancement Course is conducted entirely in the laboratory (L – T – P – J: 0 – 0 – 4 – 0) and has no theory lectures. The 60 practical hours are organised as fifteen four-hour laboratory sessions on digital product design using Autodesk Inventor and Fusion 360. Each session begins with a short demonstration and is followed by individual or small-group hands-on work; the procedure, results and inferences of every experiment are recorded in a laboratory record / digital portfolio.

Experiments 1–5 (initial skills), 6–10 (intermediate skills) and 11–15 (advanced skills and mini project) correspond to CAT–1, CAT–2 and CAT–3 of the Assessment Scheme respectively.

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
1	**Sketching, Constraints and Parametric Part Modelling**	Create fully constrained 2D sketches and 3D parts (shaft, flange, pulley) using extrude, revolve and pattern features; edit the design through parameters.	CO1	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
2	**Feature-Based Modelling of Machine Components**	Model a bracket, coupling and housing using sweep, loft, rib, shell, fillet and chamfer features; implement design changes through parametric constraints.	CO1	4
3	**Surface Modelling and Sheet Metal Design**	Model a plastic enclosure using surface tools; design a sheet-metal bracket with flanges and bends and generate its flat pattern.	CO1	4
4	**Bottom-Up Assembly Modelling**	Assemble a gear pair and a bearing–shaft system using joints and constraints; manage components and verify degrees of freedom.	CO2	4
5	**Assembly of Mechanical Systems**	Develop assemblies of a mechanical vice, coupling and pneumatic cylinder; carry out interference and clearance checks.	CO2	4
6	**Motion Study of Mechanisms**	Define joints and drives and simulate a four-bar or cam–follower mechanism; extract displacement and velocity of components.	CO2	4
7	**Exploded Views and Assembly Animation**	Create exploded views, assembly/disassembly animations and a storyboard for a mechanical assembly.	CO3	4
8	**Materials, Appearance and Photorealistic Rendering**	Assign materials and appearances, set up lighting and environment, and render product images.	CO3	4
9	**Product Animation and Presentation**	Produce a product presentation video with camera paths and component animation.	CO3	4
10	**Cloud Rendering and Visual Design Review**	Use cloud rendering and design-review/markup tools to prepare and review a visualisation package of a consumer product.	CO3	4
11	**Engineering Drawings with GD&T and BOM**	Prepare orthographic, sectional and detail drawings with dimensions, tolerances and GD&T annotations; generate the Bill of Materials (BOM).	CO4	4
12	**Static Stress Simulation of Components**	Apply material, constraints and loads to a bracket/support; run static stress analysis and interpret stress, displacement and factor of safety.	CO4	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
13	**Topology Optimization and Additive Manufacturing Preparation**	Perform a basic topology optimization; export STL, set build orientation and supports, and prepare the model for 3D printing.	CO4	4
14	**Cloud Collaboration and Generative Design**	Work in a shared team project (version control, review and markup) and run a generative design study with defined loads, constraints and objectives.	CO5	4
15	**Mini Digital Product Design Project**	Take a product from concept to documentation—parts, assembly, drawings, simulation, rendering and prototype-ready files—and present it.	CO5	4
Total Practical Hours				**60**

Laboratory Resources: Software, Tools and Equipment

- Autodesk Fusion 360
- Fusion 360 Simulation Workspace
- Autodesk Inventor Professional
- Fusion 360 rendering and animation workspaces
- Fusion 360 team project / cloud collaboration tools and Generative Design
- 3D-printing slicer software (Cura / PrusaSlicer) and FDM 3D printer

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	3	–	3	–	–	–	–	–	–	3	–
CO2	2	–	3	–	2	–	–	–	–	–	–	3	2
CO3	1	–	–	–	1	–	–	–	–	2	–	3	–
CO4	2	–	–	2	3	–	–	–	–	–	–	2	–
CO5	2	–	3	–	3	–	–	–	2	–	–	3	–

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

Understand AI-assisted generative design workflows for optimized digital product development using Fusion 360.

Example Activity:

Develop an optimized lightweight mechanical component using Fusion 360 Generative Design tools:

- Create the initial CAD geometry.
- Apply loading and boundary conditions.
- Define manufacturing constraints.
- Generate AI-assisted design alternatives.
- Compare optimized design outputs based on weight and stiffness.

Assessment Scheme

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Experiments 1–5	CO1 / CO2 (L1–L2)	20	Fundamental understanding. Quiz / Demonstration / Assignment / Concept Test / Viva
CAT–2 – Apply	Experiments 6–10	CO2 / CO3 (L2–L3)	20	Application of skills. Hands-on Task / Practical Exercise / Problem Solving / Software Activity / Lab Task
CAT–3 – Analyze / Create	Experiments 11–15	CO3 / CO4 / CO5 (L3–L6)	20	Analysis, creation and application. Mini Project / Case Study / Design Task / Practical Demonstration / Presentation
Continuous Skill Assessment	Entire Course	As applicable	20	Practical Performance / Technical Assignment / Activity
Final Skill Demonstration	Entire Course	As applicable	20	Practical Demonstration / Viva / Project Presentation
Total CIA			**100**	**No SEE**

Suggested Reading

Reference Books

- Randy Shih, Parametric Modeling with Autodesk Inventor, SDC Publications.
- Ibrahim Zeid, CAD/CAM Theory and Practice, McGraw Hill.
- P. N. Rao, CAD/CAM Principles and Applications, McGraw Hill.

Additional Resources

- Autodesk Learning Portal
- Autodesk Design Academy

- Fusion 360 Official Tutorials
- Autodesk University
- NPTEL – Product Design and Development

DLI Course Mapped

Building Digital Twins for Physical AI With NVIDIA Omniverse
https://learn.nvidia.com/

DLI Learning Path

- AI-Assisted Generative Design
- Digital Product Design using Fusion 360
- Smart Manufacturing and Digital Prototyping
- Industry 4.0 Product Engineering

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

(As per Choice Based Credit System)	
Course Code: 26MDE5118	**Semester:** I
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Basic aerodynamics and CFD knowledge, Python/NumPy proficiency, deep learning fundamentals, and familiarity with PyTorch.	
Course Type: Skill Enhancement Course (SEC)	**Hours/Week:** 04 **Total Hours:** 60 Hrs – 60 Hrs (Practical) **Credits:** 02
L – T – P – J: 0 – 0 – 4 – 0	

Course Vision

This course aims to develop next-generation computational engineering skills using NVIDIA AI Physics technologies by integrating Physics-Informed Neural Networks (PINNs), scientific machine learning, accelerated computing, and digital twin technologies for rapid engineering simulation, design optimization, and intelligent product development.

Course Objectives

Students will be able to:

- Preprocess complex CFD mesh data (VTP, STL) into formats suitable for neural operators and Graph Neural Networks.
- Understand, train, and validate the DoMINO neural operator architecture for accurate surface predictions.
- Master graph-based data preparation, including mesh-to-graph conversion and METIS partitioning for scalable GNN training.
- Implement a distributed training workflow for the X-MeshGraphNet model on large-scale graph data.
- Deploy and query a pre-trained model as a production-ready NVIDIA Inference Microservice (NIM).
- Create high-fidelity, interactive visualizations of aerodynamic flow fields using NVIDIA Omniverse Kit-CAE.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Preprocess complex CFD mesh data in VTP and STL formats for neural operator and Graph Neural Network applications.	L3
CO2	Train and validate the DoMINO neural operator architecture for accurate aerodynamic surface predictions.	L5
CO3	Perform mesh-to-graph conversion and METIS-based graph partitioning for scalable Graph Neural Network training.	L3
CO4	Implement distributed training workflows for the X-MeshGraphNet model using large-scale graph data.	L3
CO5	Deploy pre-trained AI models through NVIDIA Inference Microservices (NIM) and visualize aerodynamic flow fields using NVIDIA Omniverse Kit-CAE.	L6

Broad Course Description

This Skill Enhancement Course introduces students to emerging AI Physics technologies that combine artificial intelligence with physical laws to solve engineering problems significantly faster than conventional simulation approaches.

This course provides a comprehensive, hands-on introduction to building and deploying AI surrogate models for external aerodynamics, bridging the gap between time-intensive Computational Fluid Dynamics (CFD) simulations and the rapid predictive power of deep learning. You will learn to leverage the NVIDIA Physics NeMo framework to accelerate traditional engineering workflows by orders of magnitude, without sacrificing accuracy. This course covers the complete end-to-end pipeline, from processing raw 3D mesh data to training state-of-the-art models and visualizing results in an interactive digital twin environment.

Detailed Laboratory / Practical Syllabus

Laboratory Experiments and Practical Activities

This Skill Enhancement Course is conducted entirely in the laboratory (L – T – P – J: 0 – 0 – 4 – 0) and has no theory lectures. The 60 practical hours are organised as fifteen four-hour laboratory sessions on AI Physics-based accelerated simulation using NVIDIA Modulus. Each session begins with a short demonstration and is followed by individual or small-group hands-on work; the procedure, results and inferences of every experiment are recorded in a laboratory record / digital portfolio.

Experiments 1–5 (initial skills), 6–10 (intermediate skills) and 11–15 (advanced skills and mini project) correspond to CAT–1, CAT–2 and CAT–3 of the Assessment Scheme respectively.

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
1	CFD Data Import and Geometry Visualization	Import VTP/STL files; inspect mesh structure and physical variables; visualize geometries using PyVista. Output: Validated CFD geometry and visualization.	CO1	4
2	CFD Data Preprocessing for Neural Operators	Extract surface coordinates and physical quantities; convert mesh and physics data into NumPy arrays; organize training data. Output: Structured and preprocessed CFD dataset.	CO1	4
3	DoMINO Neural Operator Architecture and Data Preparation	Study DoMINO architecture, input features, and prediction workflow; prepare input data for surface pressure and shear stress prediction. Output: Prepared model inputs and architecture workflow.	CO2	4
4	DoMINO Model Training Using PyTorch	Implement the training loop; configure model parameters, loss functions, and optimization settings; monitor training performance. Output: Trained DoMINO model and loss plots.	CO2	4
5	DoMINO Inference and Prediction Validation	Run inference using the trained model; compare predicted and reference surface pressure and shear stress; calculate prediction errors. Output: Validated predictions and error metrics.	CO2	4
6	Introduction and Setup of NVIDIA NIM	Study NVIDIA Inference Microservices architecture; configure the inference environment and endpoint; identify input/output requirements. Output: Configured NIM inference workflow.	CO3	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
7	API-Based Aerodynamic Analysis Using DoMINO	Make API calls to a pre-trained DoMINO model; process prediction responses; analyze surface pressure and shear stress for vehicle geometries. Output: Aerodynamic prediction results for a vehicle geometry.	CO3	4
8	CFD Mesh-to-Graph Conversion Using DGL	Convert mesh nodes and connectivity into graph structures; define graph nodes, edges, and associated attributes. Output: CFD graph representation.	CO4	4
9	Graph Feature Engineering and Mesh Coarsening	Perform mesh coarsening; engineer node and edge features; validate graph connectivity and save graph datasets. Output: Prepared graph dataset for GNN training.	CO4	4
10	X-MeshGraphNet Architecture and METIS Partitioning	Explore X-MeshGraphNet architecture; partition large graphs using METIS; prepare graph partitions for scalable training. Output: Partitioned graph dataset and training configuration.	CO4	4
11	X-MeshGraphNet Training on Multiple GPUs	Configure and execute the training script using partitioned graphs; monitor training loss and computational performance. Output: Trained GNN model and performance results.	CO4	4
12	Introduction to NVIDIA Omniverse Kit-CAE	Set up the visualization environment; import CFD geometry and prediction results; inspect aerodynamic surface fields. Output: Interactive visualization scene.	CO5	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
13	Programmatic Visualization of Neural Operator Predictions	Integrate model inference outputs with visualization workflows; generate surface-field visualizations and analyze aerodynamic distributions. Output: Programmatically visualized aerodynamic predictions.	CO5	4
14	Interactive Flow Visualization and Analysis	Generate streamlines and volume renderings; examine flow structures and aerodynamic features using NVIDIA Omniverse Kit-CAE. Output: Interactive flow visualization.	CO5	4
15	Integrated Practical Assessment: CFD Digital Twin Workflow	Execute an end-to-end workflow involving CFD data preprocessing, model inference, and visualization; interpret results and submit a technical report. Output: Demonstrated CFD digital twin workflow and report.	CO5	4
Total Practical Hours				**60**

Laboratory Resources: Software, Tools and Equipment

- Tools, libraries, and frameworks used: Python, PyTorch, PyVista, Deep Graph Library (DGL), NVIDIA Physics NeMo, and NVIDIA Omniverse.
- For additional hands-on training through the NVIDIA Deep Learning Institute, visit www.nvidia.com/dli.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	1	–	3	–	–	–	–	–	–	–	2
CO2	2	–	3	–	3	–	–	–	–	–	–	–	–
CO3	2	1	–	–	3	–	–	–	–	–	–	–	2
CO4	2	–	3	–	3	–	–	–	–	–	–	–	2
CO5	2	–	3	–	3	–	–	–	–	–	–	–	–

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

Understand how AI Physics combines machine learning and governing physical laws to accelerate engineering simulations and digital engineering workflows.

Example Activity:

Develop an AI-assisted fluid flow prediction model using NVIDIA Modulus.

- Define governing equations and boundary conditions.
- Develop a Physics-Informed Neural Network model.
- Train the model using engineering constraints.
- Compare predictions with conventional CFD solutions.
- Analyze computational speedup and prediction accuracy.

Students shall:

- Evaluate AI-generated simulation outputs using engineering fundamentals.
- Compare PINN-based solutions with conventional numerical methods.
- Analyze reliability and limitations of AI Physics models.
- Assess computational efficiency and engineering accuracy.
- Reflect on ethical and professional implications of AI-driven engineering design.

Assessment Scheme

Skill Enhancement Course (Practical)

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Experiments 1–5	CO1 / CO2 (L1–L2)	20	Fundamental understanding. Quiz / Demonstration / Assignment / Concept Test / Viva
CAT–2 – Apply	Experiments 6–10	CO2 / CO3 (L2–L3)	20	Application of skills. Hands-on Task / Practical Exercise / Problem Solving / Software Activity / Lab Task
CAT–3 – Analyze / Create	Experiments 11–15	CO3 / CO4 / CO5 (L3–L6)	20	Analysis, creation and application. Mini Project / Case Study / Design Task / Practical Demonstration / Presentation
Continuous Skill Assessment	Entire Course	As applicable	20	Practical Performance / Technical Assignment / Activity
Final Skill Demonstration	Entire Course	As applicable	20	Practical Demonstration / Viva / Project Presentation

Total CIA			**100**	**No SEE**

Suggested Reading

Reference Books

- Steven L. Brunton and J. Nathan Kutz, Data-Driven Science and Engineering, Cambridge University Press.
- Kevin P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press.
- J.N. Reddy, An Introduction to Computational Fluid Dynamics and Finite Element Methods, McGraw Hill.

Additional Resources

- NVIDIA Deep Learning Institute (DLI)
- NVIDIA Modulus Documentation
- NVIDIA Omniverse Learning Resources
- Physics-Informed Neural Networks Tutorials
- NPTEL – Scientific Machine Learning

DLI Course Mapped

Fundamentals of Accelerated Computing with CUDA
https://learn.nvidia.com/

DLI Learning Path

- Fundamentals of Accelerated Computing with CUDA
- Physics-Informed Machine Learning
- Scientific Computing with NVIDIA GPUs
- Digital Twins with NVIDIA Omniverse

Modern Materials and Manufacturing Technology

(As per Choice Based Credit System)	
Course Code: 26MDE5201	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Materials, Manufacturing Processes, Mechanics of Materials	
Course Type: IPCC	**Hours/Week:** 05 **Total Hours:** 45 Hrs Theory + 30 Hrs Lab **Credits:** 04
L – T – P – J: 3 – 0 – 2 – 0	

Course Vision

This course aims to develop advanced knowledge in modern engineering materials, emerging manufacturing technologies, and sustainable production systems. The course enables postgraduate learners to analyse material behaviour, evaluate advanced manufacturing methods, and apply intelligent manufacturing concepts for industrial applications in aerospace, automotive, biomedical, electronics, and energy sectors.

Course Objectives

Students will be able to:

- Assess advanced engineering materials and their microstructural behaviour for industrial applications.
- Analyse modern material processing techniques and surface engineering methods.
- Evaluate advanced manufacturing technologies including additive manufacturing and smart manufacturing systems.
- Apply sustainability concepts, AI-assisted manufacturing, and Industry 4.0 practices in production environments.
- Develop analytical and research-oriented skills for material selection, process optimization, and intelligent manufacturing systems

Course Outcomes (CO)

CO	Course Outcome	BTL

CO	Course Outcome	BTL
CO1	Explain advanced material processing routes and surface engineering techniques used to enhance the performance and reliability of engineering components.	L2
CO2	Apply non-traditional machining, additive manufacturing, and precision manufacturing techniques to industrial component manufacturing.	L3
CO3	Analyze smart manufacturing systems, Industry 4.0 technologies, and AI-driven practices for process monitoring and production optimization.	L4
CO4	Apply sustainable manufacturing concepts, circular-economy strategies, and life cycle assessment to material and process selection.	L3
CO5	Analyze emerging manufacturing technologies and sustainable supply-chain considerations for industrial and research applications.	L4
CO6	Perform mechanical, metallurgical, and metrology tests and additive-manufacturing experiments on conventionally and additively manufactured specimens and analyze process–property relationships.	L4

Broad Course Description

This course provides a comprehensive understanding of advanced materials and modern manufacturing technologies used in contemporary engineering industries. The course focuses on the relationship between material structure, properties, processing, and performance while emphasizing advanced manufacturing systems capable of producing high-quality, precision-engineered products.

Learners will explore advanced engineering materials including composites, smart materials, biomaterials, nanomaterials, and high-performance alloys. The course further introduces advanced manufacturing processes such as additive manufacturing, laser processing, micro-machining, non-traditional machining, and intelligent manufacturing systems.

The course integrates modern concepts of Industry 4.0, digital manufacturing, automation, AI-assisted production, and sustainable manufacturing practices. Students will gain exposure to material characterization techniques, process optimization strategies, and real-world industrial applications in sectors such as aerospace, automotive, biomedical engineering, semiconductor manufacturing, and renewable energy systems.

The course also encourages research-oriented learning through case studies, simulation-based analysis, industrial problem-solving, and technology evaluation activities.

Detailed Course Syllabus

Course Modules

Module 1: Material Processing and Surface Engineering (9 Hours)

Advanced casting techniques, powder metallurgy, rapid solidification, and severe plastic deformation processes; heat treatment and thermomechanical processing of advanced alloys. Surface engineering: surface modification and hardening (laser surface hardening, ion implantation) and coating technologies (thermal spray, PVD/CVD). Surface integrity and wear resistance analysis.

Industrial Applications: *Cutting tool coatings, aerospace surface protection systems, biomedical surface treatments, corrosion-resistant components.*

Module 2: Advanced Manufacturing Technologies (9 Hours)

Principles of advanced manufacturing systems. Non-traditional machining processes including EDM, ECM, USM, AJM, WJM, AWJM, laser beam machining, electron beam machining, and plasma arc machining. Additive manufacturing technologies: stereolithography, selective laser sintering, fused deposition modelling, direct metal laser sintering, binder jetting, and hybrid manufacturing systems. Precision and micro-manufacturing processes. Process parameters, quality analysis, process optimization, and defect analysis in advanced manufacturing.

Engineering Applications: *Aerospace components, customized biomedical implants, precision mould manufacturing, semiconductor fabrication.*

Module 3: Smart Manufacturing and Industry 4.0 (9 Hours)

Introduction to smart manufacturing systems. Cyber-physical systems, digital twins, Industrial Internet of Things (IIoT), cloud manufacturing, digital manufacturing platforms, and intelligent automation. Robotics and collaborative robots in manufacturing. AI and machine learning applications in process monitoring, predictive maintenance, quality inspection, and production optimization. Sensors, data acquisition systems, manufacturing analytics, and digital supply chain integration.

Industrial Applications: Smart factories, automated production systems, predictive maintenance systems, AI-based quality control systems.

Module 4: Sustainable Manufacturing Practices (9 Hours)

Concepts of sustainable manufacturing and circular economy. Green materials and eco-friendly manufacturing practices. Energy-efficient manufacturing systems, waste minimization, remanufacturing, recycling technologies, and life cycle assessment (LCA).

Industrial Applications: *Renewable energy systems, electric vehicle manufacturing, sustainable production systems, green factories.*

Module 5: Emerging Manufacturing Technologies (9 Hours)

Sustainable supply chain management and carbon footprint analysis. Emerging technologies including bio-manufacturing, nano-manufacturing, flexible manufacturing systems, autonomous production systems, and quantum-enabled manufacturing research trends.

Industrial Applications: *Bio-manufactured tissue scaffolds and implants, nano-manufactured coatings and sensors, flexible manufacturing cells for mixed-model production, autonomous production lines, and supply-chain carbon-footprint assessment.*

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	3	–	–	1	–	–	–	–	–	–	–	3
CO2	2	2	–	–	1	–	–	–	–	–	–	–	3
CO3	1	–	1	–	1	–	–	–	–	–	–	3	2
CO4	2	3	2	–	2	–	–	–	–	–	–	1	3
CO5	2	3	1	–	2	–	3	–	–	–	–	2	3
CO6	2	2	–	3	3	–	–	–	–	–	–	2	3

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand how Artificial Intelligence and data-driven manufacturing systems improve production efficiency, quality assurance, predictive maintenance, and process optimization in advanced manufacturing industries.

Example Activities:

- Analyse manufacturing datasets to identify process variations and defect trends using AI tools.
- Develop predictive maintenance models for rotating machinery using machine learning algorithms.
- Evaluate sensor data from smart manufacturing systems for process optimization.
- Simulate AI-assisted additive manufacturing parameter optimization.
- Compare conventional and AI-assisted manufacturing quality inspection systems using industrial case studies.

Laboratory / Practical Component

The following lab experiments can be carried out using various machines: Lab Experiments

- Perform tensile testing of conventionally manufactured and additively manufactured specimens and compare mechanical properties.
- Conduct hardness testing (Rockwell/Vickers/Brinell) on metallic and polymer AM specimens.
- Perform impact testing and fracture analysis of additively manufactured components.
- Study microstructural characterization using optical microscopy and SEM images for printed materials.

- Analyse surface roughness and dimensional accuracy of additively manufactured components using metrology tools.
- Conduct wear and tribological testing of coated and additively manufactured samples.
- Develop CAD models and generate STL files for additive manufacturing applications.
- Perform slicing, build orientation analysis, and support structure optimization for complex geometries.
- Analyse the effect of process parameters such as layer thickness, print speed, and infill density on dimensional accuracy in FDM printing.

AI-Integrated Lab Exercises (Indicative)

- Develop AI/ML models for predicting surface roughness or dimensional deviation using process parameter datasets.
- Perform predictive maintenance analysis of additive manufacturing systems using sensor
- Simulate digital twin-based monitoring of additive manufacturing processes.
- Analyse energy consumption and sustainability metrics of additive versus conventional manufacturing systems.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises three Continuous Assessment Tests (CAT–1, CAT–2, CAT–3) aligned with course modules and Bloom's Taxonomy levels, one Mid-Semester Examination (MSE), and one Continuous Assessment component, as detailed in the table below.

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 20	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity

Continuous Laboratory Assessment	Lab Integrated Component – Experiments / Practical Activities	CO6 (L2–L5)	10	Continuous evaluation of practical skills, experimental procedure, application of concepts, data collection and analysis, interpretation of results, troubleshooting and technical documentation. Lab Performance / Experiment Execution / Lab Record / Practical Assignment / Simulation or CAD Activity / Mini Project / Problem-Based Practical Activity
Total CIA	Modules 1–5		60	
SEE	Comprehensive Syllabus	As applicable	40	End-Semester Examination
Grand Total			**100**	

Recommended Tools

- CAD and Modelling: SolidWorks, CATIA, Autodesk Fusion 360
- Additive Manufacturing Software: Cura, Simplify3D, Materialise Magics, Ultimaker Cura
- Simulation and Analysis: ANSYS Additive Suite, Abaqus, COMSOL Multiphysics
- Hybrid Manufacturing and CAM: Siemens NX, Mastercam, PowerMill
- Materials Characterization Tools: ImageJ, OriginPro, MATLAB
- AI Tools: Python (TensorFlow, Scikit-learn), NVIDIA CUDA Toolkit, NVIDIA Nsight Systems, Machine Learning Libraries for Manufacturing Analytics

Suggested Reading

Primary Textbooks

- William D. Callister Jr. and David G. Rethwisch, Materials Science and Engineering: An Introduction, Wiley India, 10th Edition, 2018.
- Mikell P. Groover, Fundamentals of Modern Manufacturing: Materials, Processes and Systems, Wiley, 7th Edition, 2020.
- Kalpakjian S. and Schmid S. R., Manufacturing Engineering and Technology, Pearson Education, 8th Edition, 2020.

Reference Books

- V. Raghavan, Materials Science and Engineering: A First Course, PHI Learning, 6th Edition, 2015.
- Dieter G. E., Engineering Design: Materials and Processing Approach, McGraw Hill Education, 5th Edition, 2013.
- Gibson I., Rosen D., and Stucker B., Additive Manufacturing Technologies, Springer, 3rd Edition, 2021.

Additional Resources

- NPTEL: Introduction to Materials Science and Engineering – IIT Kanpur
- NPTEL: Advanced Manufacturing Processes – IIT Kharagpur
- NPTEL: Additive Manufacturing Technologies – IIT Hyderabad
- MIT OpenCourseWare – Manufacturing Processes and Systems
- ASTM Standards for Additive Manufacturing Technologies

DLI Course Mapped

Fundamentals of Deep Learning for Manufacturing
https://learn.nvidia.com/

DLI Learning Path

- AI-Assisted Manufacturing and Process Optimization
- Smart Materials and Digital Manufacturing
- Predictive Maintenance for Manufacturing Systems

Advanced Composite Materials for Design

(As per Choice Based Credit System)	
Course Code: 26MDE5202	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Materials, Mechanics of Materials, Manufacturing Processes	
Course Type: IPCC	**Hours/Week:** 05 **Total Hours:** 45 Hrs Theory + 30 Hrs Lab **Credits:** 04
L – T – P – J: 3 – 0 – 2 – 0	

Course Vision

This course aims to develop advanced knowledge of composite materials and their application in mechanical and structural design. The course enables postgraduate learners to understand the constituents, manufacturing, and mechanics of polymer, metal, ceramic, and natural-fibre composites, and to apply classical lamination theory and failure analysis for the design of lightweight, high-performance components used in aerospace, automotive, sports, marine, and biomedical engineering.

Course Objectives

Students will be able to:

- Classify composite material systems and their constituents, including matrices, reinforcements, and interfaces, for engineering design applications.
- Apply micromechanics and classical lamination theory to predict the stiffness and strength of composite laminates.
- Evaluate manufacturing processes for polymer, metal, and ceramic matrix composites, including natural-fibre and hybrid composite systems.
- Analyse failure mechanisms, damage tolerance, and fatigue behaviour of composite structures under mechanical and environmental loading.
- Apply computational tools and AI-assisted methods for composite material selection, laminate design, and damage prediction.

Course Outcomes (CO)

CO	Course Outcome	BTL

CO	Course Outcome	BTL
CO1	Classify composite material systems and explain their characteristics and design philosophy for selection in engineering applications.	L2
CO2	Apply micromechanics and the rule of mixtures to predict the elastic properties and strength of unidirectional composites.	L3
CO3	Analyze orthotropic lamina and laminate behavior using classical lamination theory (A, B, and D matrices) for stacking-sequence design.	L4
CO4	Apply failure criteria (Maximum Stress, Tsai–Hill, Tsai–Wu, and Hashin) to predict failure, damage, and durability of composite structures.	L3
CO5	Analyze composite manufacturing, testing, and simulation approaches, including AI-assisted tools, to optimize lightweight laminate design.	L4
CO6	Fabricate and test composite laminates as per ASTM standards and analyze tensile, flexural, impact, interlaminar shear, and environmental-degradation results.	L4

Broad Course Description

This course provides a comprehensive treatment of composite materials for design applications, covering material constituents, manufacturing processes, and mechanical behaviour of fibre-reinforced and particulate composites. The course establishes the relationship between constituent properties, fibre architecture, processing methods, and resulting laminate performance.

Learners will study classical lamination theory, micromechanics of lamina, and macromechanics of laminates, along with failure theories specific to composites such as Tsai-Hill, Tsai-Wu, and maximum stress criteria. The course further introduces advanced and sustainable composite systems including natural-fibre composites, hybrid metal matrix composites, and nano-reinforced composites relevant to lightweight structural design.

The course integrates modern manufacturing techniques such as hand lay-up, filament winding, resin transfer moulding, pultrusion, and autoclave curing, along with non-destructive evaluation and damage tolerance assessment. Students will gain exposure to computational tools for laminate design and AI-assisted approaches for defect prediction and material optimisation in aerospace, automotive, and biomedical applications.

The course also encourages research-oriented learning through case studies, simulation-based laminate analysis, industrial problem-solving, and technology evaluation activities.

Detailed Course Syllabus

Course Modules

Module 1: Introduction to Advanced Composite Materials and Design Philosophy (9 Hours)

Definition, characteristics, and need for composite materials in engineering design; classification by matrix (polymer, metal, ceramic, carbon–carbon) and by reinforcement (particulate, fiber-reinforced, sandwich); natural fiber, hybrid, and nanocomposites; role of fibers, matrix, interface, and interphase; isotropic, anisotropic, and orthotropic material behavior; specific strength and specific stiffness; advantages and limitations of composites; design philosophy for lightweight structures.

Engineering Applications: Aerospace panels, automobile body parts, Formula Student components, pressure vessels, wind turbine blades, marine structures, biomedical implants, sports equipment, drone frames, robotic arms, and lightweight machine components.

Module 2: Micromechanics of Composite Materials (9 Hours)

Fiber volume fraction, matrix volume fraction, mass fraction, density of composites, void content, rule of mixtures, longitudinal modulus, transverse modulus, shear modulus, major and minor Poisson's ratio, strength prediction of unidirectional composites, load sharing between fiber and matrix, critical fiber length, fiber orientation effects, short fiber and continuous fiber composites, particulate composites, influence of interface bonding, thermal expansion behavior, moisture absorption and environmental effects.

Engineering Applications: Design of unidirectional laminates, glass fiber/epoxy components, carbon fiber/epoxy structures, natural fiber composites, FRP panels, lightweight brackets, composite leaf springs, and automotive reinforcement panels.

Module 3: Macromechanics of Lamina and Laminate Design (9 Hours)

Stress–strain relationship for orthotropic lamina, engineering constants of lamina, reduced stiffness matrix, transformed stiffness matrix, stress transformation, strain transformation, off-axis loading, angle-ply lamina, cross-ply lamina, symmetric and antisymmetric laminates, balanced laminates, laminate stacking sequence, Classical Laminate Theory, A, B and D matrices, coupling effects, extensional stiffness, bending stiffness, design of laminate layups for stiffness, strength and dimensional stability.

Engineering Applications: Design of composite plates, aircraft skins, vehicle panels, pressure tubes, racing car body panels, drone propellers, machine covers, structural laminates, and composite repair patches.

Module 4: Failure, Damage and Durability of Composite Structures (9 Hours)

Failure modes in composites: fiber breakage, matrix cracking, fiber–matrix debonding, delamination, and compression failure; impact, fatigue, creep, and environmental (moisture and temperature) effects. Failure criteria: Maximum Stress, Maximum Strain, Tsai–Hill, Tsai–Wu, and Hashin criteria; first-ply failure and progressive damage concept. Fracture toughness and damage tolerance. Non-destructive testing of composites: ultrasonic testing, thermography, and visual inspection.

Engineering Applications: Failure analysis of composite shafts, composite pressure vessels, aircraft panels, wind turbine blades, leaf springs, helmets, crash structures, sandwich panels, and adhesive-bonded composite joints.

Module 5: Manufacturing, Testing, Simulation and AI-Assisted Composite Design (9

Hours)

Manufacturing processes for composites: hand and spray lay-up, compression moulding, vacuum bagging, resin transfer moulding, filament winding, pultrusion, and autoclave/prepreg processing; overview of machining, joining, and additive manufacturing of composites. Testing of composites (tensile, compression, flexural, shear, impact, and fatigue), ASTM standards, and design allowables. Finite element analysis of composite laminates: material cards, ply orientation, and mesh considerations. AI-assisted material selection and stacking-sequence optimization using surrogate models. Sustainability and recycling of composite materials.

Engineering Applications: Manufacturing and design of composite tubes, panels, gears, shafts, leaf springs, bicycle frames, aerospace parts, drone structures, pressure vessels, sports equipment, protective structures, and sustainable natural fiber composite products.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	3	–	1	–	–	–	–	–	–	1	3
CO2	3	–	–	–	1	–	–	–	–	–	–	–	2
CO3	2	3	–	–	1	–	–	–	–	–	–	3	3
CO4	2	3	–	–	2	–	–	–	–	–	–	–	3
CO5	2	–	3	–	3	–	–	–	–	–	–	2	3
CO6	2	2	–	3	2	–	–	–	–	–	–	2	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Understand how Artificial Intelligence and machine learning can be applied to predict composite material properties, optimise laminate design, and detect manufacturing or in-service defects in composite structures.

Example Activities:

- Use AI/ML tools to predict elastic constants of a lamina from constituent properties and compare with micromechanics calculations.
- Develop a machine-learning model to classify composite defect types from simulated ultrasonic C-scan data.
- Evaluate AI-assisted optimisation of stacking sequence for a laminate subjected to combined loading.
- Simulate AI-assisted prediction of fatigue life for a composite laminate using available datasets.
- Compare conventional and AI-assisted approaches for natural-fibre composite property prediction using industrial case studies.

Laboratory / Practical Component

The following lab experiments can be carried out using available materials and testing equipment:
Lab Experiments

- Fabricate a glass/carbon-fibre reinforced polymer laminate using hand lay-up and determine fibre volume fraction.
- Determine tensile, flexural, and interlaminar shear strength of composite laminates as per ASTM standards.
- Perform impact testing (Izod/Charpy) on composite specimens and analyse damage modes.
- Study fibre-matrix interfacial bonding using microscopy of fractured composite specimens.
- Fabricate and test a natural-fibre (jute/sisal/coir) reinforced composite and compare properties with synthetic-fibre composites.
- Conduct water absorption and environmental degradation testing on natural-fibre composites.
- Develop a laminate stacking-sequence model using classical lamination theory in a spreadsheet or MATLAB.
- Perform non-destructive evaluation (ultrasonic/tap test) of a composite laminate to detect delamination.
- Analyse the effect of fibre orientation and stacking sequence on the stiffness of a laminate using simulation software.

AI-Integrated Lab Exercises (Indicative)

- Develop an AI/ML model to predict tensile strength of a composite laminate from fibre volume fraction and orientation data.
- Perform automated defect classification from composite C-scan images using a trained classification model.
- Simulate digital-twin-based monitoring of a composite structure under cyclic loading.
- Analyse the sustainability and cost trade-offs of natural-fibre versus synthetic-fibre composite systems using computational tools.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises three Continuous Assessment Tests (CAT–1, CAT–2, CAT–3) aligned with course modules and Bloom's Taxonomy levels, one Mid-Semester Examination (MSE), and one Continuous Assessment component, as detailed in the table below.

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study

Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 20	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Continuous Laboratory Assessment	Lab Integrated Component – Experiments / Practical Activities	CO6 (L2–L5)	10	Continuous evaluation of practical skills, experimental procedure, application of concepts, data collection and analysis, interpretation of results, troubleshooting and technical documentation. Lab Performance / Experiment Execution / Lab Record / Practical Assignment / Simulation or CAD Activity / Mini Project / Problem-Based Practical Activity
Total CIA	Modules 1–5		60	
SEE	Comprehensive Syllabus	As applicable	40	End-Semester Examination
Grand Total			**100**	

Recommended Tools

- CAD and Modelling: SolidWorks, CATIA, Autodesk Fusion 360
- Composite Design Software: ESAComp, HyperSizer, ANSYS Composite PrepPost (ACP)
- Simulation and Analysis: ANSYS, Abaqus, MATLAB
- Micromechanics and Laminate Tools: CompositePro, Classical Lamination Theory spreadsheets
- Materials Characterization Tools: ImageJ, OriginPro, MATLAB
- AI Tools: Python (TensorFlow, Scikit-learn), NVIDIA CUDA Toolkit, Machine Learning Libraries for Materials Informatics

Suggested Reading

Primary Textbooks

- R. M. Jones, Mechanics of Composite Materials, Taylor & Francis, 2nd Edition, 2018.

- Autar K. Kaw, Mechanics of Composite Materials, CRC Press, 2nd Edition, 2006.
- P. K. Mallick, Fiber-Reinforced Composites: Materials, Manufacturing, and Design, CRC Press, 4th Edition, 2021.

Reference Books

- Isaac M. Daniel and Ori Ishai, Engineering Mechanics of Composite Materials, Oxford University Press, 2nd Edition, 2006.
- B. D. Agarwal, L. J. Broutman, and K. Chandrashekhara, Analysis and Performance of Fiber Composites, Wiley, 3rd Edition, 2017.
- A. R. Bunsell and J. Renard, Fundamentals of Fibre Reinforced Composite Materials, IOP Publishing, 2005.

Additional Resources

- NPTEL: Mechanics of Composite Materials and Structures – IIT Kanpur
- NPTEL: Analysis and Design of Composite Structures – IIT Madras
- NPTEL: Introduction to Natural Fibre Composites – IIT Roorkee
- MIT OpenCourseWare – Mechanics of Fibre-Reinforced Composites
- ASTM Standards for Composite Materials Testing (D3039, D2344, D256)

DLI Course Mapped

Fundamentals of Deep Learning for Materials Science
https://learn.nvidia.com/

DLI Learning Path

- AI-Assisted Composite Laminate Design
- Digital Twin for Composite Structures
- Machine Learning for Materials Characterization

Generative AI for Mechanical Design

(As per Choice Based Credit System)	
Course Code: 26MDE5203	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: CAD Modeling, Engineering Design Fundamentals, Basics of Artificial Intelligence	
Course Type: PCC	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop competency in applying Generative Artificial Intelligence techniques for innovative mechanical product design, optimization, simulation-driven design exploration, and intelligent engineering automation. The course empowers learners to integrate AI-driven methodologies with modern CAD/CAE tools for creating sustainable, lightweight, manufacturable, and performance-oriented engineering designs.

Course Objectives

Students will be able to:

- Understand the fundamentals of Generative AI and its applications in mechanical design engineering.
- Apply AI-assisted generative design methodologies for component and product development.
- Explore topology optimization, AI-driven CAD automation, and simulation-integrated design workflows.
- Develop intelligent design solutions using machine learning and generative modeling tools.
- Demonstrate AI-assisted design validation, manufacturing feasibility, and sustainable product development practices.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the fundamentals of Generative AI and its role in modern mechanical design workflows.	L2

CO	Course Outcome	BTL
CO2	Apply AI-assisted generative design approaches and CAD automation to develop optimized mechanical components.	L3
CO3	Analyze topology optimization and simulation-driven design alternatives using AI-based methods.	L4
CO4	Apply machine learning models to predict performance and support decision-making in mechanical design workflows.	L3
CO5	Analyze manufacturability, sustainability, and performance of AI-generated mechanical designs for manufacturing integration.	L4

Broad Course Description

This course introduces the concepts and industrial applications of Generative Artificial Intelligence in Mechanical Design Engineering. The course emphasizes AI-driven design methodologies that automatically generate multiple design alternatives based on engineering constraints, material properties, manufacturing requirements, and performance objectives.

Learners will gain practical exposure to:

- AI-assisted generative design workflows
- Topology optimization techniques
- AI-enabled CAD modeling and design automation
- Machine learning applications in engineering design

Detailed Course Syllabus

Course Modules

Module 1: Introduction to Generative AI in Mechanical Design (9 Hours)

Introduction to Artificial Intelligence and Generative AI. Evolution of AI in engineering design. AI-driven design methodologies. Fundamentals of Generative Design. Design constraints, objectives, and optimization parameters. Role of machine learning in CAD/CAE. Overview of Generative Design tools and workflows. Human-AI collaborative engineering design process.

Engineering Applications: Lightweight automotive brackets, aerospace structural components, biomedical implants.

Module 2: AI-Assisted Generative Design and CAD Automation (9 Hours)

Generative design workflow in CAD systems. Parametric modeling and AI-driven geometry creation. Constraint-based design generation. AI-assisted feature recognition. Design space exploration. Automated concept generation using AI. CAD automation using scripting and APIs. Integration of AI with Fusion 360 and Siemens NX.

Engineering Applications: Robotic arm design, automotive suspension components, industrial fixture development.

Module 3: Topology Optimization and Simulation-Driven Design (9 Hours)

Introduction to topology optimization. Material distribution methods. Structural optimization objectives and constraints. AI-assisted finite element analysis. Multi-objective optimization techniques. Design for weight reduction and performance improvement. Simulation-driven iterative design refinement. AI-based performance prediction methods.

Engineering Applications: Aircraft wing brackets, EV chassis structures, turbine blade optimization.

Module 4: Machine Learning Applications in Mechanical Design (9 Hours)

Introduction to Machine Learning for design engineering. Supervised and unsupervised learning concepts. Predictive modeling for material selection and design performance. AI-based failure prediction. Neural networks in engineering design. Data-driven design optimization. Digital twins and smart product development.

Engineering Applications: Predictive maintenance systems, smart manufacturing systems, fatigue life prediction.

Module 5: Sustainable Generative Design and Manufacturing Integration (9 Hours)

Design for Additive Manufacturing (DfAM). Sustainable product development using AI. Manufacturability analysis of AI-generated designs. AI-assisted process planning. Material optimization and lifecycle analysis. Ethical considerations in AI-driven engineering. Future trends in Generative AI for mechanical industries.

Engineering Applications: 3D printed lightweight structures, eco-friendly consumer products, AI-assisted production systems.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	3	–	2	–	–	–	–	–	–	1	3
CO2	2	–	3	–	3	–	–	–	–	–	–	3	3
CO3	2	3	2	–	3	–	–	–	–	–	–	2	3
CO4	2	–	3	–	3	–	–	–	–	–	–	3	–
CO5	2	3	3	–	2	–	3	–	–	–	–	3	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM:

Understand how Generative AI can automatically create optimized engineering designs based on design objectives, constraints, and performance criteria.

Example Activity:

Develop an AI-assisted generative design workflow for a lightweight mechanical bracket:

- Define loading and boundary conditions.
- Specify material and manufacturing constraints.
- Generate multiple AI-driven design alternatives.
- Perform topology optimization and simulation analysis.
- Compare weight, strength, and manufacturability of generated designs.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Autodesk Fusion 360
- Siemens NX Generative Design
- ANSYS Topology Optimization
- nTopology
- MATLAB / Python
- TensorFlow / Scikit-learn

Suggested Reading

Primary Textbooks

- Ibrahim Zeid, CAD/CAM Theory and Practice, McGraw Hill.
- Mike Rosen, AI and Generative Design for Engineering Applications, Springer.

Reference Books

- Ian Goodfellow, Yoshua Bengio, Aaron Courville, Deep Learning, MIT Press.
- David Bourgin, Generative Design: Visualize, Program, and Create with Processing, Princeton Architectural Press.
- Klaus Schwab, The Fourth Industrial Revolution, Crown Publishing.
- Andreas Gebhardt, Additive Manufacturing, Hanser Publications.

Additional Resources

- NPTEL – Artificial Intelligence in Manufacturing
- Autodesk Generative Design Learning Resources
- Siemens NX Design Optimization Tutorials
- Coursera – AI for Everyone
- MIT OpenCourseWare – Machine Learning for Engineering

DLI Course Mapped

Fundamentals of Deep Learning https://learn.nvidia.com/

DLI Learning Path

- NVIDIA Deep Learning Institute – Fundamentals of Deep Learning
- AI for Manufacturing and Design Optimization
- Generative AI Applications in Engineering Design

Mechatronic System Design

(As per Choice Based Credit System)	
Course Code: 26MDE5204	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Fundamentals of Mechanics, Electronics, Control Systems and Programming	
Course Type: PCC	**Hours/Week:** 03 **Total Hours:** 45 Hrs **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to provide students with comprehensive knowledge of intelligent mechatronic systems by integrating mechanical engineering, electronics, control systems, and embedded computing. The course emphasizes modelling, analysis, control, and implementation of smart mechatronic systems for modern industrial and robotic applications.

Course Objectives

Students will be able to:

- Gain knowledge of mechatronic system elements and integrated system design methodologies.
- Understand microprocessors and microcontrollers used in intelligent mechatronic applications.
- Develop mathematical models of mechatronic systems and analyze system dynamics.
- Apply control system concepts and stability analysis techniques for intelligent systems.
- Analyze digital signal processing techniques and advanced mechatronic applications.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the architecture, programming model, and interfacing of microprocessors and microcontrollers used in mechatronic systems.	L2
CO2	Analyze mathematical models and dynamic behavior of mechatronic systems.	L4
CO3	Apply feedback control and stability analysis techniques to	L3

CO	Course Outcome	BTL
	mechatronic systems.	
CO4	Apply digital systems, data acquisition, and signal processing techniques in mechatronic system design.	L3
CO5	Analyze advanced mechatronic applications and the integrated design of components, sensors, actuators, and controllers.	L4

Broad Course Description

This course introduces intelligent mechatronic system design through the integration of mechanical systems, electronics, sensors, actuators, embedded systems, and control engineering. The course covers system modelling, microcontroller-based interfacing, feedback control design, and digital signal processing for intelligent automation systems. Students gain exposure to advanced mechatronic applications including robotic systems, smart manufacturing, and microfabrication technologies. The course prepares students to design and implement modern intelligent mechatronic systems used in industrial automation and robotics.

Detailed Course Syllabus

Course Modules

Module 1: Microprocessors and Microcontrollers for Mechatronics (9 Hours)

Microprocessor Building Blocks, Combinational and Sequential Logic Elements, Memory and Timing Fundamentals, Primitive Microprocessor Concepts, Microcontrollers for Mechatronics, TIVA Programming Basics, PWM and QEI Interfaces.

Engineering Applications: *Embedded Motion Control Systems, Motor Speed Control using PWM, Encoder-Based Position Monitoring Systems.*

Module 2: Mathematical Modeling of Mechatronic Systems (9 Hours)

Mathematical Modeling of Mechatronic Systems, Modeling of Friction and DC Motor, Lagrange Formulation for System Dynamics, Dynamics of 2R Manipulator, Simulation using MATLAB, Selection of Sensors and Actuators.

Engineering Applications: *Robotic Manipulator Modeling, Motor Drive Simulation, Intelligent Motion Control System Design.*

Module 3: Control Systems and Stability Analysis (9 Hours)

Concept of Feedback and Closed Loop Control, Mathematical Representation of Systems, Linear Control Design, Basics of Lyapunov Theory, Stability Concepts and Lyapunov Theorems, Trajectory

Tracking Control.

Engineering Applications: *Autonomous Robotic Control, Stability Analysis of Intelligent Systems, Precision Motion Tracking Systems.*

Module 4: Digital Systems (9 Hours)

Signal Sampling and Signal Processing, Digital Systems and Filters, Practical Mechatronic System Implementation.

Engineering Applications: *Digital signal processing in automation, digital filtering of sensor signals in motor drives, and embedded digital controllers for smart mechatronic devices*

Module 5: Advanced Mechatronic Applications (9 Hours)

Case Studies of Novel Mechatronic Systems, 3D Micro-Printer, Hele Shaw System for Microfabrication.

Engineering Applications: *Intelligent additive manufacturing systems, microfabrication systems (3D micro-printer, Hele-Shaw cell), and case studies of novel mechatronic devices*

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	–	2	–	1	–	–	–	–	–	–	–	–
CO2	3	3	–	–	1	–	–	–	–	–	–	–	–
CO3	1	3	2	–	1	–	–	–	–	–	–	–	–
CO4	2	3	1	–	2	–	–	–	–	–	–	–	–
CO5	2	3	1	–	2	–	–	–	–	–	–	–	–

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand how Artificial Intelligence, embedded intelligence, and data-driven control systems improve sensing, automation, motion control, system stability, predictive maintenance, and real-time decision-making in intelligent mechatronic systems.

Example Activities:

- Analyse sensor data from intelligent mechatronic systems to identify system response, faults, and performance variations using AI tools.
- Develop machine learning models for predictive maintenance and fault diagnosis of motors, actuators, and robotic systems.

- Evaluate microcontroller-based control systems using AI-assisted monitoring and real-time feedback analysis.
- Simulate AI-assisted trajectory tracking and motion control optimization for robotic manipulators and autonomous systems.
- Compare conventional PID control and AI-based intelligent control techniques for precision mechatronic applications.
- Use MATLAB/Simulink or Python tools to model and optimize intelligent mechatronic system dynamics and stability.
- Investigate AI-supported digital signal processing methods for filtering, sensor fusion, and intelligent automation systems.
- Apply data-driven approaches to optimize smart manufacturing, robotic automation, and intelligent embedded system performance.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- MATLAB / Simulink
- TIVA C Series LaunchPad
- Keil µVision IDE
- Proteus Simulation Software
- LabVIEW
- Embedded C Programming Tools

Suggested Reading

Reference Books

- Nitaigour Premchand Mahalik, Mechatronics: Principles, Concepts and Applications, McGraw Hill.
- K. P. Ramachandran and G. K. Vijayaraghavan, Mechatronics: Integrated Mechanical Electronic Systems, Wiley.
- Katsuhiko Ogata, Modern Control Engineering, Pearson.
- Franklin, Powell and Emami-Naeini, Feedback Control of Dynamic Systems, Pearson.
- Robert H. Bishop, The Mechatronics Handbook, CRC Press.

Additional Resources

- NPTEL Courses on Mechatronics
- MATLAB and Simulink Documentation
- ARM Cortex Microcontroller Tutorials
- TIVA C Series Technical Documentation
- IEEE Research Papers on Intelligent Mechatronic Systems

DLI Course Mapped

Fundamentals of Deep Learning for Robotics and Mechatronics
https://learn.nvidia.com/

DLI Learning Path

- AI-Assisted Mechatronic System Design
- Intelligent Motion Control Systems

- Predictive Maintenance for Mechatronic Systems

Product Lifecycle Engineering in Industry 4.0

(As per Choice Based Credit System)	
Course Code: 26MDE5205	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Fundamentals of Manufacturing Processes and Industrial Engineering, Fundamentals of CAD/CAM and Digital Manufacturing, Fundamentals of Data Analytics and Engineering Data Management, Basic Programming Knowledge using Python/MATLAB for Engineering Applications	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

To empower design-engineering graduates with the expertise to lead digital transformation through integrated product lifecycle strategies, leveraging Industry 4.0 technologies and Authentic Intelligence to create sustainable, innovative, and market-responsive products in a connected global ecosystem.

Course Objectives

Students will be able to:

- Understand the fundamental elements, platforms, and digital drivers of Product Lifecycle Management (PLM) in the Industry 4.0 landscape.
- Develop structure and competency in Collaborative Product Development (CPD) and Digital Manufacturing utilizing IoT and Digital Twins.
- Master engineering data management, configuration structures, and change management processes for complex product variants.
- Integrate Artificial Intelligence (AI) and Machine Learning for predictive maintenance, process optimization, and design decision support.
- Formulate and implement end-to-end PLM strategies that align with corporate objectives and sustainable manufacturing principles.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the evolution of PLM, digital enterprise concepts, product data management, and digital drivers such as IoT, cloud manufacturing, and big data.	L2
CO2	Apply collaborative product development, digital mock-up, virtual prototyping, and concurrent engineering practices using cloud-based PLM systems.	L3
CO3	Apply standardized product data models, configuration structures, BOM management, and engineering change workflows (ECR/ECO) to manage product variants.	L3
CO4	Apply digital twin, cyber-physical production system, and IIoT concepts to real-time monitoring and predictive maintenance in smart factories.	L3
CO5	Analyze PLM assessment frameworks, lifecycle costing, and sustainable product development strategies to support digital transformation planning.	L4

Broad Course Description

This course provides a comprehensive immersion into the digital threads that connect every stage of a product's life—from conceptualization and design to manufacturing, service, and retirement—within the Industry 4.0 paradigm. Students will explore the convergence of PLM with the Industrial Internet of Things (IIoT), Cloud Manufacturing, and Smart Factories, gaining hands-on experience in managing complex product data structures and materials data models.

Emphasis is placed on Collaborative Product Development (CPD) and the strategic application of Artificial Intelligence to enhance decision-making and predictive analytics. By the end of the course, students will be equipped to lead the digital transformation in manufacturing, ensuring product consistency, quality, and sustainability in an increasingly intelligent and connected global enterprise

Detailed Course Syllabus

Course Modules

Module 1: PLM & Digital Drivers (9 Hours)

Core Topics: Evolution of PLM, PLM Paradigm, Digital Enterprise Concepts, Product Data Management (PDM), Digital Drivers (IoT, Cloud Manufacturing, Big Data), Product Data Issues and Lifecycle Integration.

Engineering Applications: Selection and deployment of PLM platforms for automotive, aerospace, and manufacturing industries.

Module 2: Collaborative Development (9 Hours)

Core Topics: Engineering Vaulting, Product Reuse Strategies, Collaborative Product Development (CPD), Digital Mock-Up, Virtual Prototyping, Virtual Testing, Concurrent Engineering.

Engineering Applications: Design collaboration in globally distributed engineering teams using cloud-based PLM systems.

Module 3: Configuration & Change (9 Hours)

Core Topics: Standardized Product Data Models, Configuration Structures, BOM Consistency, Variant Management, Engineering Change Requests (ECR), Engineering Change Orders (ECO), Workflow Automation.

Engineering Applications: Managing product variants and configuration control in mass-customized manufacturing industries.

Module 4: Digital Twin & Smart Factory (9 Hours)

Core Topics: Digital Twin Concepts, Cyber-Physical Production Systems (CPPS), Smart Factories, Predictive Maintenance, Industrial IoT Integration.

Engineering Applications: Real-time monitoring of manufacturing systems, energy management, and predictive asset maintenance.

Module 5: Strategy & Sustainability (9 Hours)

Core Topics: PLM Assessment Frameworks, Lifecycle Costing (LCC), Sustainable Product Development, Circular Economy, Design for Environment (DfE), Digital Transformation Strategy.

Engineering Applications: Developing sustainable digital transformation roadmaps for global manufacturing enterprises.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	3	–	–	2	–	3	–	–	–	–	–	–
CO2	2	–	3	2	3	–	–	–	–	–	–	3	–
CO3	2	–	–	–	1	–	–	–	2	–	2	–	–
CO4	2	3	3	2	3	–	–	–	–	–	–	2	3
CO5	2	–	3	–	2	–	3	–	–	–	–	2	–

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Understand how Artificial Intelligence and data analytics enable intelligent decision-making across the design, manufacturing, and end-of-life stages of the

product lifecycle.

Example Activities:

- Analyse product lifecycle management (PLM) datasets to identify patterns in design changes and engineering change requests using AI tools.
- Develop a predictive model for product quality based on manufacturing process parameters.
- Evaluate AI-assisted digital-thread and digital-twin concepts for lifecycle tracking of a product.
- Simulate AI-based demand forecasting for product lifecycle planning.
- Compare conventional PLM workflows with AI-augmented PLM systems using an industrial case study.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
Grand Total	—	—	**100**	—

Recommended Tools

- Simulation: MATLAB/Simulink, FlexSim, Witness
- Visualization: Siemens Teamcenter, FlashPrint, 3DXpert.
- AI Tools: Python (Numpy, Pandas), TensorFlow, PyTorch

Suggested Reading

Reference Books

- Michael Grieves, Product Lifecycle Management: Driving the Next Generation of Lean Thinking, McGraw-Hill, 2006.
- Udhayan Elongovan, Product Life Cycle Management (PLM): A Digital Journey using IIoT, CRC Press, 2020.

Additional Resources

- Kari Ulrich and Steven D. Eppinger, Product Design & Development, McGraw Hill.
- Mikell P. Groover, Automation, Production Systems, and Computer-Integrated Manufacturing, Pearson

DLI Course Mapped

Fundamentals of Accelerated Computing for Digital Manufacturing
https://learn.nvidia.com/

DLI Learning Path

- Digital Thread and Digital Twin for PLM
- AI-Assisted Product Lifecycle Analytics
- Industry 4.0 for Product Engineering

Computational Engineering Modeling and Simulation

(As per Choice Based Credit System)	
Course Code: 26MDE5206	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Basic Engineering Mathematics, Numerical Methods, Basic Programming	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop advanced computational modeling and simulation skills for engineering applications using mathematical models, numerical techniques, and modern simulation tools for analysis and optimization of engineering systems.

Course Objectives

Students will be able to:

- Understand fundamentals of engineering modeling and simulation techniques.
- Develop mathematical models for engineering systems.
- Apply numerical methods for computational analysis.
- Analyse engineering systems using simulation approaches.
- Use computational tools for optimization and engineering decision-making.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the fundamental concepts of mathematical modeling of engineering systems.	L2
CO2	Apply numerical methods for solving engineering analysis problems.	L3
CO3	Develop computational models for engineering simulations using	L3

CO	Course Outcome	BTL
	appropriate simulation techniques.	
CO4	Apply simulation and optimization methods to predict the performance of engineering systems.	L3
CO5	Analyze advanced simulation results and engineering analytics for complex computational models.	L4

Broad Course Description

This course provides a comprehensive understanding of computational engineering modeling and simulation techniques for engineering applications. It covers mathematical

modeling, numerical methods, system simulation, optimization techniques, and computational analysis of engineering systems.

Students will learn how to develop mathematical and computational models, perform simulations, interpret engineering data, and analyse system behavior under different operating conditions. The course emphasizes engineering problem-solving, simulation-based analysis, and optimization approaches for complex engineering systems.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Engineering Modeling (9 Hours)

Introduction to computational engineering, mathematical modeling principles, modeling of physical systems, governing equations, dimensional analysis, and model formulation techniques.

Engineering Applications: Modeling of thermal systems, fluid flow systems, structural systems, and energy systems.

Module 2: Numerical Methods for Engineering Analysis (9 Hours)

Numerical solutions of algebraic and differential equations, interpolation techniques, numerical integration, finite difference methods, and error analysis.

Engineering Applications: Heat transfer analysis, fluid mechanics computations, stress analysis, and engineering data approximation.

Module 3: Computational Simulation Techniques (9 Hours)

Simulation concepts, deterministic and stochastic simulations, discrete and continuous system simulation, Monte Carlo methods, and computational workflows.

Engineering Applications: Manufacturing system simulation, process analysis, reliability modeling, and system performance evaluation.

Module 4: Engineering System Modeling and Optimization (9 Hours)

Dynamic system modeling, optimization techniques, sensitivity analysis, parameter estimation, and multi-variable engineering system analysis.

Engineering Applications: Optimization of thermal systems, manufacturing processes, energy systems, and mechanical system performance.

Module 5: Advanced Simulation and Engineering Analytics (9 Hours)

Finite element concepts, computational fluid dynamics (CFD) fundamentals, engineering analytics, validation and verification of models, uncertainty analysis, and engineering decision-making.

Engineering Applications: Structural analysis, flow simulation, process optimization, predictive maintenance, and digital engineering applications.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	–	1	–	2	–	–	–	–	–	–	–	–
CO2	1	3	–	–	2	–	–	–	–	–	–	–	2
CO3	2	–	3	–	3	–	–	–	–	–	–	–	3
CO4	2	3	1	–	3	–	–	–	–	–	–	–	–
CO5	2	3	–	–	3	–	–	–	–	–	–	–	3

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand how Artificial Intelligence and machine learning techniques can accelerate, complement, and validate computational engineering models and simulations.

Example Activities:

- Develop a surrogate/reduced-order model using machine learning to approximate a computationally expensive simulation.
- Apply AI-assisted mesh generation or adaptive refinement strategies for a computational model.
- Evaluate the use of physics-informed machine learning for solving governing differential equations.
- Simulate AI-based parameter calibration for a computational model against experimental or benchmark data.
- Compare simulation runtime and accuracy of conventional numerical solvers versus AI-accelerated solvers.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of

60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Simulation Software: MATLAB / ANSYS / COMSOL / Simulink
- Programming: Python / MATLAB
- Visualization: ParaView / Excel / basic plotting tools
- AI-Assisted Tools: ChatGPT for model interpretation and validation

Suggested Reading

Primary Textbooks

- Steven C. Chapra and Raymond P. Canale, Numerical Methods for Engineers, McGraw Hill, 7th Edition, 2015.
- Singiresu S. Rao, Engineering Optimization: Theory and Practice, Wiley, 4th Edition, 2009.

Reference Books

- J. N. Reddy, An Introduction to the Finite Element Method, McGraw Hill, 3rd Edition, 2005.
- William L. Oberkampf and Christopher J. Roy, Verification and Validation in Scientific Computing, Cambridge University Press, 2010.

Additional Resources

- NPTEL: Computational Methods in Engineering – IIT Madras
- NPTEL: Numerical Methods and Simulation – IIT Bombay
- MATLAB and COMSOL Multiphysics Documentation and Tutorials

DLI Course Mapped

Fundamentals of Accelerated Computing and Numerical Analysis
https://learn.nvidia.com/

DLI Learning Path

- Accelerated Computing for Simulation
- AI-Assisted Computational Modeling
- Physics-Informed Machine Learning for Engineering Simulation

Data-Driven Design Optimization Techniques

(As per Choice Based Credit System)	
Course Code: 26MDE5207	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mathematics, Statistics, Optimization Techniques, Basic Programming	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop advanced skills in optimization, engineering analytics, and data-driven design techniques for solving complex engineering problems using mathematical, statistical, and computational approaches.

Course Objectives

Students will be able to:

- Understand fundamentals of optimization and engineering analytics.
- Apply linear and nonlinear optimization techniques for engineering problems.
- Develop analytical and computational optimization models.
- Analyse engineering systems using data-driven approaches.
- Apply optimization and decision-making techniques for engineering design improvement.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the formulation of optimization problems and the solution of linear programming problems using graphical, simplex, Big-M, and two-phase methods and duality.	L2
CO2	Apply integer programming, transportation and assignment models, shortest-path algorithms, and CPM/PERT techniques to network and	L3

CO	Course Outcome	BTL
	logistics optimization problems.	
CO3	Analyze single-variable, unconstrained, and constrained nonlinear optimization problems using KKT conditions and region-elimination methods.	L4
CO4	Apply direct and indirect search methods, dynamic programming, geometric programming, and sensitivity analysis to computational design optimization.	L3
CO5	Analyze multi-objective and multi-attribute decision-making problems and predictive engineering analytics for engineering design under uncertainty.	L4

Broad Course Description

This course provides a comprehensive understanding of optimization and data-driven design techniques for engineering applications. It covers linear programming, integer programming, transportation and assignment problems, project management techniques, nonlinear optimization, decision-making methods, and computational optimization approaches.

Students will learn how to formulate engineering optimization problems, analyse engineering datasets, develop predictive optimization models, and apply decision-making strategies for complex engineering systems. The course emphasizes engineering applications, system optimization, and analytical approaches for modern engineering design.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Optimization and Linear Programming (9 Hours)

Introduction to optimization, formulation of linear programming problems (LPP), graphical solution methods, simplex method, Big-M method, two-phase method, duality theory, and post-optimality analysis.

Engineering Applications: Resource allocation, production planning, process optimization, and engineering decision-making problems.

Module 2: Integer Programming and Network Optimization (9 Hours)

Integer programming, transportation problems, assignment problems, shortest path algorithms, travelling salesman problem, project management, CPM and PERT techniques.

Engineering Applications: Logistics optimization, scheduling, manufacturing systems, project planning, and network analysis in engineering systems.

Module 3: Classical and Nonlinear Optimization Techniques (9 Hours)

Single variable optimization, unconstrained multivariable optimization, constrained nonlinear programming, KKT conditions, region elimination techniques, Fibonacci method, golden section search, and interpolation methods.

Engineering Applications: Optimization of thermal systems, structural design, fluid flow systems, and manufacturing parameter optimization.

Module 4: Computational Optimization and Design Analytics (9 Hours)

Direct and indirect search methods, dynamic programming, separable programming, geometric programming, constrained optimization techniques, and sensitivity analysis.

Engineering Applications: Computational design optimization, engineering system modeling, energy system optimization, and reliability analysis.

Module 5: Multi-Objective Decision-Making and Engineering Analytics (9 Hours)

Multi-objective decision-making, multi-attribute decision-making, predictive engineering analytics, engineering decision support systems, optimization under uncertainty, and engineering case studies.

Engineering Applications: Sustainable engineering design, industrial optimization, smart manufacturing systems, and engineering performance evaluation.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	3	–	1	–	–	–	–	–	–	2	3
CO2	2	1	2	–	1	–	–	–	–	–	–	2	2
CO3	2	3	3	–	1	–	–	–	–	–	–	1	2
CO4	2	3	1	–	3	–	–	–	–	–	–	–	3
CO5	1	–	2	2	1	–	–	–	–	–	–	–	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Understand how Artificial Intelligence and machine learning methods enhance data-driven design optimization for engineering systems.

Example Activities:

- Develop a machine-learning-based surrogate model to replace expensive objective-function evaluations in an optimization loop.
- Apply AI-assisted multi-objective optimization, combining genetic algorithms with ML surrogates, to a design problem.
- Evaluate Bayesian optimization techniques for efficient design-space exploration.
- Simulate AI-assisted sensitivity analysis to identify critical design variables.

- Compare classical gradient-based optimization with AI-assisted metaheuristic optimization for a design case study.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Optimization Software: MATLAB / LINGO / GAMS / Excel Solver
- Programming & Analytics: Python / MATLAB
- Statistical Tools: Minitab / JMP
- AI-Assisted Tools: ChatGPT for optimization interpretation and analytical validation

Suggested Reading

Primary Textbooks

- Singiresu S. Rao, Engineering Optimization: Theory and Practice, Wiley, 4th Edition, 2009.
- Kalyanmoy Deb, Optimization for Engineering Design: Algorithms and Examples, PHI Learning, 2nd Edition, 2012.

Reference Books

- Jasbir S. Arora, Introduction to Optimum Design, Academic Press, 4th Edition, 2016.
- Trevor Hastie, Robert Tibshirani, and Jerome Friedman, The Elements of Statistical Learning, Springer, 2nd Edition, 2009.

Additional Resources

- NPTEL: Optimization Methods – IIT Madras
- NPTEL: Data-Driven Design and Analytics – IIT Kharagpur
- MATLAB Optimization Toolbox and GAMS Documentation

DLI Course Mapped

Fundamentals of Deep Learning for Data-Driven Optimization
https://learn.nvidia.com/

DLI Learning Path

- AI-Assisted Design Optimization
- Machine Learning for Engineering Analytics
- Data-Driven Decision-Making Systems

Parallel and High-Performance Computing for Engineering

(As per Choice Based Credit System)	
Course Code: 26MDE5208	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mathematics, Basic Programming Knowledge, Numerical Methods	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course develops the ability to apply parallel and high-performance computing techniques for solving large-scale engineering and computational problems. The learners gain knowledge in parallel architectures, distributed computing, GPU acceleration, CUDA programming concepts, and high-performance numerical methods for modern engineering applications.

Course Objectives

Students will be able to:

- Understand the fundamentals of parallel computing and high-performance computing architectures.
- Explore distributed and shared memory programming models for engineering simulations.
- Demonstrate parallel programming concepts using multicore and GPU-based computing techniques.
- Apply high-performance computing methods for engineering analysis, optimization, and large-scale simulations.
- Introduce NVIDIA CUDA-enabled acceleration techniques for advanced engineering computation.

Course Outcomes (CO)

CO	Course Outcome	BTL

CO	Course Outcome	BTL
CO1	Explain parallel computing architectures, performance metrics, and high-performance computing concepts relevant to engineering applications.	L2
CO2	Apply shared-memory and distributed-memory programming models to parallelize computational engineering problems.	L3
CO3	Develop GPU-accelerated programs using NVIDIA CUDA for engineering simulations.	L3
CO4	Apply high-performance numerical methods to engineering problems and measure speed-up, scalability, and efficiency.	L3
CO5	Analyze advanced HPC applications and large-scale engineering computations to identify performance bottlenecks and scalability limits.	L4

Broad Course Description

This course introduces students to the concepts and methodologies of parallel and high-performance computing for engineering applications. The course focuses on computational acceleration techniques used in modern engineering simulations, optimization, artificial intelligence, and large-scale data processing.

Learners will gain knowledge in parallel computing architectures, distributed systems, multicore processing, GPU acceleration, numerical parallel algorithms, and performance optimization techniques. The course also emphasizes engineering applications involving finite element simulations, computational fluid dynamics, AI-assisted simulations, and large-scale manufacturing analytics.

Beyond conventional computing methods, the course introduces NVIDIA GPU computing technologies and CUDA-enabled parallel processing frameworks for accelerating engineering computations and scientific workflows.

Through theoretical concepts, industrial case studies, and computational problem-solving approaches, the course nurtures the ability to develop efficient high-performance computing solutions for modern engineering systems.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Parallel and High-Performance Computing (9 Hours)

Introduction to High-Performance Computing (HPC): Evolution and importance of HPC,

Computational challenges in engineering, Flynn's classification of computer architectures, Parallel processing concepts, Performance metrics, Speedup, Efficiency and Scalability. Shared memory and distributed memory architectures, Multicore processors and cluster computing fundamentals.

Engineering Applications: Large-scale finite element simulations, Computational fluid dynamics analysis.

Module 2: Parallel Programming Models and Architectures (9 Hours)

Parallel programming paradigms, Thread-level and process-level parallelism, Shared memory programming concepts, Distributed computing fundamentals, Message Passing Interface (MPI) concepts, OpenMP basics, Synchronization and communication techniques, Load balancing and scheduling methods.

Engineering Applications: Structural analysis acceleration, Parallel thermal simulations.

Module 3: GPU Computing and NVIDIA CUDA Fundamentals (9 Hours)

Introduction to GPU Computing: CPU vs GPU architectures, Heterogeneous computing concepts, NVIDIA GPU architecture overview. CUDA Programming Fundamentals: CUDA toolkit installation, CUDA compiler (NVCC), CUDA kernels, Threads, Blocks and Grids, Memory hierarchy, Shared memory, Global memory and Device memory management. GPU-based matrix operations and parallel numerical methods.

Engineering Applications: Parallel matrix multiplication, GPU-accelerated engineering computations.

Module 4: High-Performance Numerical Methods for Engineering (9 Hours)

Parallel numerical algorithms, Parallel linear algebra techniques, Sparse matrix computations, Parallel iterative methods, Domain decomposition methods, Parallel optimization techniques, HPC applications in Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), Topology optimization and AI-driven simulations.

Engineering Applications: High-speed topology optimization, AI-assisted multiphysics simulations.

Module 5: Advanced HPC Applications and Future Trends (9 Hours)

Cloud-based HPC systems, AI and HPC convergence, Digital twin systems, Edge computing for engineering applications, Real-time simulation techniques, HPC in Industry 4.0 environments, Energy-efficient computing, Quantum computing overview, Ethical and sustainability considerations in large-scale computing systems.

Engineering Applications: Smart manufacturing systems, Real-time industrial digital twins.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	1	–	1	–	–	–	–	–	–	–	2
CO2	2	3	1	–	3	–	–	–	–	–	–	–	2
CO3	2	–	2	–	3	–	–	–	–	–	–	–	2
CO4	2	2	1	–	2	–	–	–	–	–	–	–	3

CO5	2	–	2	–	3	–	–	–	–	–	–	–	2

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

Example:

- Develop a parallel matrix multiplication algorithm using CUDA-enabled GPU computing.
- Compare CPU and GPU execution times for engineering computations.
- Analyze thread allocation and memory management strategies.
- Visualize computational performance improvements using profiling tools.
- Interpret scalability and efficiency results for engineering applications.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Python and MATLAB for numerical computing
- OpenMP and MPI programming environments
- NVIDIA CUDA Toolkit
- NVIDIA Nsight Systems and Nsight Compute
- NVIDIA Omniverse for simulation workflows
- ANSYS HPC and Parallel Simulation Tools

Suggested Reading

Reference Books

- Shane Cook, “CUDA Programming: A Developer’s Guide to Parallel Computing with GPUs”, Morgan Kaufmann.
- David B. Kirk and Wen-mei W. Hwu, “Programming Massively Parallel Processors: A
- Hands-on Approach”, Elsevier.
- Ananth Grama, Anshul Gupta, George Karypis and Vipin Kumar, “Introduction to Parallel Computing”, Pearson.
- Georg Hager and Gerhard Wellein, “Introduction to High Performance Computing for Scientists and Engineers”, CRC Press.

Additional Resources

- NPTEL: Parallel Computing Courses
- NVIDIA CUDA Documentation
- OpenMP Official Documentation
- MPI Tutorial Resources

DLI Course Mapped

Fundamentals of Accelerated Computing with CUDA C/C++
https://learn.nvidia.com/

DLI Learning Path

- Accelerated Computing and GPU Programming
- CUDA Programming for Engineering Applications

- High-Performance Scientific Computing

Additive and Hybrid Manufacturing Systems

(As per Choice Based Credit System)	
Course Code: 26MDE5209	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Manufacturing Processes, Engineering Materials, CAD/CAM	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop advanced knowledge in additive manufacturing and hybrid manufacturing technologies for the design, development, and production of complex engineering components. The course enables postgraduate learners to understand digital manufacturing workflows, optimize additive manufacturing processes, integrate conventional and additive techniques, and apply intelligent manufacturing strategies for aerospace, biomedical, automotive, defense, and energy applications.

Course Objectives

Students will be able to:

- Understand the principles, classifications, and applications of additive manufacturing technologies.
- Analyse process parameters, materials, and design methodologies used in additive manufacturing systems.
- Evaluate hybrid manufacturing systems integrating additive and subtractive manufacturing techniques.
- Apply digital manufacturing, Industry 4.0, and AI-assisted process optimization concepts in additive manufacturing.
- Develop research-oriented analytical skills for sustainable and intelligent manufacturing systems.

Course Outcomes (CO)

CO	Course Outcome	BTL

CO	Course Outcome	BTL
CO1	Explain the principles, process mechanisms, and classifications of additive manufacturing technologies for industrial applications.	L2
CO2	Analyze additive manufacturing materials, process parameters, and design strategies for product development and optimization.	L4
CO3	Apply hybrid manufacturing techniques combining additive and conventional manufacturing methods for precision engineering applications.	L3
CO4	Apply digital manufacturing workflows and AI-assisted techniques to smart additive manufacturing processes.	L3
CO5	Analyze sustainability, economic feasibility, quality control, and emerging trends in additive and hybrid manufacturing technologies.	L4

Broad Course Description

This course provides comprehensive knowledge of additive manufacturing and hybrid manufacturing technologies used in modern engineering industries. The course focuses on layer-by-layer manufacturing principles, digital manufacturing workflows, material-process interactions, and intelligent manufacturing systems.

Learners will study major additive manufacturing processes including vat photopolymerization, material extrusion, powder bed fusion, directed energy deposition, binder jetting, and sheet lamination. The course further introduces hybrid manufacturing systems that combine additive manufacturing with subtractive machining, laser processing, and precision finishing operations.

The course emphasizes design for additive manufacturing (DfAM), topology optimization, process parameter optimization, process simulation, and quality assurance methodologies. Students will gain exposure to AI-assisted manufacturing analytics, smart manufacturing concepts, real-time monitoring systems, and sustainable manufacturing practices.

Applications in aerospace, biomedical engineering, automotive manufacturing, electronics, tooling, energy systems, and customized product development are integrated throughout the courses.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Additive Manufacturing (9 Hours)

Introduction to additive manufacturing (AM), historical development, classifications, and advantages of additive manufacturing systems. Comparison between conventional and additive manufacturing. Additive manufacturing process chain. CAD modelling, STL file generation, slicing, support generation, and process planning. Types of additive manufacturing processes according to ASTM

standards. Fundamentals of layer-by-layer fabrication and process physics. Additive manufacturing process categories: vat photopolymerization, material extrusion, material jetting, binder jetting, powder bed fusion, sheet lamination, and directed energy deposition.

Engineering Applications: Rapid prototyping, aerospace lightweight structures, customized biomedical implants, tooling applications

Module 2: Materials and Design for Additive Manufacturing (9 Hours)

Materials used in additive manufacturing: polymers, metals, ceramics, composites, bio-materials, and smart materials. Material properties and material-process interactions. Design for Additive Manufacturing (DfAM), topology optimization, lattice structures, lightweight design, generative design approaches, and functional optimization. Residual stresses, thermal distortion, anisotropic properties, process defects, and dimensional accuracy. Process parameter optimization and simulation approaches. Surface quality analysis and post-processing techniques.

Engineering Applications: Biomedical scaffolds, automotive lightweight components, aerospace structural optimization, customized consumer products.

Module 3: Hybrid Manufacturing Technologies (9 Hours)

Introduction to hybrid manufacturing systems and integrated manufacturing concepts. Combination of additive manufacturing with CNC machining, laser processing, grinding, EDM, and finishing processes. Directed energy deposition with machining integration. Hybrid process planning and machine configurations. Multi-axis hybrid manufacturing systems, robotic additive manufacturing, repair and remanufacturing systems, process monitoring, precision enhancement techniques, and adaptive process control. Hybrid manufacturing economics and industrial feasibility.

Engineering Applications: Turbine blade repair, mould and die manufacturing, aerospace component restoration, precision biomedical devices.

Module 4: Smart Additive Manufacturing and Industry 4.0 (9 Hours)

Smart manufacturing concepts in additive manufacturing. Sensors, machine vision systems, in-situ monitoring, process control, and digital twins. Industrial Internet of Things (IIoT), cloud manufacturing, cyber-physical systems, and intelligent manufacturing systems. Artificial intelligence and machine learning applications in additive manufacturing including defect prediction, process optimization, predictive maintenance, and quality inspection. Manufacturing analytics and data-driven manufacturing systems.

Engineering Applications: Smart additive manufacturing factories, AI-based defect detection systems, automated process monitoring, digital manufacturing systems.

Module 5: Sustainable and Emerging Trends in Additive and Hybrid Manufacturing (9 Hours)

Sustainable manufacturing principles in additive manufacturing. Energy consumption analysis, material utilization efficiency, recycling strategies, waste minimization, circular economy, and life cycle assessment (LCA). Economic analysis and techno-commercial feasibility of additive manufacturing systems. Emerging technologies including 4D printing, bio-printing, nano-printing, functionally graded materials, multi-material additive manufacturing, autonomous manufacturing systems, and AI-integrated manufacturing ecosystems. Challenges, standardization, certification, and future trends in additive and hybrid manufacturing.

Engineering Applications: Sustainable aerospace production, regenerative medicine, electric

vehicle manufacturing, green manufacturing systems.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	1	–	1	–	–	–	–	–	–	3	3
CO2	2	3	3	–	1	–	–	–	–	–	–	3	3
CO3	1	–	1	–	1	–	–	–	–	–	–	1	2
CO4	2	3	–	–	3	–	–	–	–	–	–	3	3
CO5	2	3	2	–	2	–	3	–	–	–	2	2	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

Example:

- a. Analyse process monitoring datasets to identify defects in additive manufacturing systems.
- b. Develop AI-assisted parameter optimization models for minimizing residual stress and distortion.
- c. Evaluate machine learning approaches for predicting surface quality and dimensional accuracy.
- d. Simulate digital twin systems for additive manufacturing process optimization.
- e. Compare conventional inspection systems with AI-based automated defect detection systems).

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- 3D Modeling & Design: SolidWorks, Autodesk Fusion 360, CATIA
- Additive Manufacturing Software: Ultimaker Cura, PrusaSlicer, Materialise Magics
- Simulation & Analysis: ANSYS Additive Suite, Autodesk Netfabb
- Hybrid Manufacturing & CNC Integration: Siemens NX Hybrid Manufacturing
- AI & Digital Manufacturing Tools: Autodesk Generative Design, MATLAB for process optimization and data analysis

Suggested Reading

Reference Books

- 3D Printing and Additive Manufacturing, World Scientific Publishing, 5th Edition, 2017.
- Additive Manufacturing Processes, McGraw Hill Education, 2019.
- Hybrid Manufacturing, Springer, 2018.
- Design for Additive Manufacturing, Wiley, 1st Edition, 2020.

Additional Resources

- NPTEL: Additive Manufacturing Processes

- NPTEL: Rapid Manufacturing
- MIT Additive Manufacturing for Innovative Design and Production
- Autodesk Fusion 360 Additive Manufacturing Tutorials
- ANSYS Additive Manufacturing Learning Resources

DLI Course Mapped

Fundamentals of Deep Learning for Additive Manufacturing
https://learn.nvidia.com/

DLI Learning Path

- AI-Assisted Additive Manufacturing Process Optimization
- Digital Twin for Hybrid Manufacturing
- Predictive Quality Control in Additive Manufacturing

Digital Twin Technologies for Smart Industrial Systems

(As per Choice Based Credit System)	
Course Code: 26MDE5210	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Basic knowledge of Manufacturing Processes, CAD/CAM, Sensors & Instrumentation, Engineering Mechanics, and Programming Fundamentals	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

To equip mechanical engineering students with a comprehensive understanding of Digital Twin technologies and their transformative role in smart industrial systems. The course bridges physical engineering systems with their virtual counterparts, enabling students to design, simulate, monitor, and optimise industrial processes using real-time data, physics-based models, and AI-driven analytics aligned with Industry 4.0 principles.

Course Objectives

Students will be able to:

- Understand the concept, architecture, and types of digital twins and their relevance to smart industrial systems.
- Apply CAD, CAE, and real-time data integration techniques for building industrial digital twins.
- Analyse hybrid digital twin architectures combining physics-based and data-driven models with edge processing, IoT, and cyber-physical systems.
- Evaluate digital twin applications for predictive control, diagnostics, virtual commissioning, and production line optimisation.
- Assess business value, KPIs, ROI, HMI/AR interfaces, and global standards governing digital twin deployment in Industry 4.0.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the concept, architecture, types, and real-world industrial applications of digital twins.	L2
CO2	Apply CAD, CAE, and real-time data integration techniques to construct industrial digital twin models.	L3
CO3	Analyze hybrid digital twin architectures integrating physics-based models, data-driven methods, IoT middleware, and cyber-physical systems.	L4
CO4	Apply digital twin implementations to predictive control, diagnostics, virtual commissioning, and production line optimization.	L3
CO5	Analyze business KPIs, ROI, HMI/AR interfaces, simulation validation methods, and industry standards for digital twin deployment.	L4

Broad Course Description

Digital Twin Technologies for Smart Industrial Systems is a professional elective course designed for B.Tech. Mechanical Engineering students. The course provides a structured exploration of digital twin technology — from foundational concepts and architectural frameworks to advanced industrial deployment scenarios. Students begin by understanding the definition, evolution, and classification of digital twins (product, process, and system types) and progress through the enabling technologies: CAD/CAE integration, real-time sensor data, physics-based and data-driven modelling, IoT middleware, edge computing, and cloud-based cyber-physical platforms.

The course dedicates significant attention to industrial applications including predictive maintenance, diagnostics, aerospace digital twins, virtual commissioning, and production line optimisation. Students also study human-machine interfaces (HMI), augmented reality (AR) for digital twins, OPC-UA and BPMN standards, business KPIs, ROI evaluation, and simulation validation methodologies.

Detailed Course Syllabus

Course Modules

Module 1: Foundations of Digital Twin Technology (9 Hours)

Digital twin: concept, definition, and evolution from CAD models to living digital replicas. Digital twin architecture: physical entity, virtual model, data link, and services layer. Types of digital twins: product digital twin, process digital twin, and system digital twin — benefits and challenges of each. Real-world industrial applications of digital twins in manufacturing, aerospace, energy, and healthcare. Comparison of digital twin with simulation, digital shadow, and digital model. Enabling

technologies: IoT, cloud computing, AI/ML, and high-fidelity simulation. Industry 4.0 context: smart factories, connected products, and autonomous systems.

Engineering Applications: Siemens MindSphere-based factory digital twin for production monitoring. GE Aviation engine digital twin for fleet health management. BMW Group virtual factory planning using digital twin technology. Healthcare: digital twin of human organs for surgical planning and drug testing.

Module 2: CAD, CAE, Real-Time Data Integration and Hybrid Digital Twins (9 Hours)

Role of CAD and CAE in building digital twin geometry and behaviour models. Integration of real-time sensor data (vibration, temperature, pressure, flow) into digital twin platforms. Data acquisition systems: SCADA, DAS, and edge gateways. Hybrid digital twins: combining physics-based models (FEA, CFD, multi-body dynamics) with data-driven models (ML regression, neural networks). Edge processing for low-latency digital twin updates. Model calibration and parameter tuning using live operational data. Data fusion techniques: Kalman filtering, Bayesian inference, sensor fusion. Digital thread concept: seamless data flow from design through manufacturing to operations.

Engineering Applications: Structural health monitoring of bridges and wind turbines using hybrid physics-ML digital twins. CNC machine tool digital twin with real-time vibration and thermal compensation. Aero-engine digital twin combining CFD models with in-flight sensor data for remaining useful life prediction. Smart HVAC system digital twin integrating building energy models with IoT sensor networks.

Module 3: IoT, Middleware, Cyber-Physical Systems and Cloud Platforms (9 Hours)

APIs and middleware for digital twin integration: REST APIs, MQTT, AMQP, and OPC-UA. Industrial IoT (IIoT) architecture for digital twin data pipelines. Cyber-physical systems (CPS): definition, architecture, and role in Industry 4.0. Cloud-based digital twin platforms: Microsoft Azure Digital Twins, AWS IoT TwinMaker, NVIDIA Omniverse, Siemens Xcelerator. Edge-cloud continuum: distributing computation between edge devices and cloud servers. Digital twin communication protocols and interoperability standards. Security and cybersecurity considerations for industrial digital twins. Scalability challenges: managing digital twins for large-scale production facilities.

Engineering Applications: Smart factory floor monitoring using Azure Digital Twins with OPC-UA connected PLCs. Predictive quality control in automotive assembly lines using cloud-based digital twin analytics. Port logistics optimisation using AWS IoT TwinMaker for container tracking and scheduling. Oil and gas pipeline monitoring using CPS-enabled digital twins with edge computing for anomaly detection.

Module 4: Predictive Control, Diagnostics, Virtual Commissioning and Production Optimisation (9 Hours)

Digital twins for predictive maintenance: remaining useful life (RUL) estimation, failure mode prediction, and condition-based diagnostics using digital twin feedback loops. Virtual commissioning: testing and validating production line control logic in a virtual environment before physical deployment. Digital twin-driven production line optimisation: throughput, bottleneck identification, scheduling, and what-if scenario analysis. Closed-loop digital twins for autonomous control and self-optimising systems. Integration of digital twins with MES and ERP.

Engineering Applications: Siemens virtual commissioning of automotive robotic welding lines. Rolls-Royce Intelligent Engine programme: in-service digital twin for predictive maintenance. Tesla Gigafactory digital twin for real-time production monitoring and optimisation. Airbus: structural

digital twin for aircraft fuselage fatigue life prediction and inspection scheduling.

Module 5: HMI, Standards, Business Value, Simulation Validation and Future Trends (9 Hours)

Human-Machine Interfaces (HMI) for digital twins: dashboards, 3D visualisation, and AR/XR interfaces for interaction and remote maintenance. Standards for digital twins: OPC-UA, Asset Administration Shell (AAS), and ISO 23247 (Digital Twin Framework for Manufacturing). Business KPIs and ROI of digital twins. Verification, validation, and uncertainty quantification (VVUQ) of digital twins; simulation tools (MATLAB/Simulink, ANSYS Twin Builder, NVIDIA Omniverse). Industrial case studies and future trends: autonomous, AI-native, and federated digital twins.

Engineering Applications: AR-based maintenance guidance for industrial robots using digital twin overlay. ROI analysis of digital twin deployment in pharmaceutical batch manufacturing. ISO 23247 compliance assessment for a smart machining centre digital twin. Real-time monitoring dashboard for a water treatment plant digital twin with predictive control.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	1	–	3	–	–	–	–	–	–	–	–
CO2	1	–	–	2	3	–	–	–	–	–	–	3	–
CO3	2	3	–	2	3	–	–	–	–	–	–	–	–
CO4	2	3	3	–	3	–	–	–	–	–	–	2	–
CO5	2	3	2	2	3	2	–	–	–	–	2	–	–

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Understand how Artificial Intelligence and machine learning form the analytical core of digital twins for real-time monitoring, prediction, and optimization of industrial systems.

Example Activities:

- Develop a machine-learning model to predict the future state of a physical asset using historical sensor data for digital-twin applications.
- Simulate AI-assisted anomaly detection in a digital twin of an industrial machine.
- Evaluate predictive maintenance strategies using digital-twin and AI-based prognostics.
- Analyse data synchronization and AI-based data-fusion techniques between physical assets and their digital twins.
- Compare conventional monitoring approaches with AI-enhanced digital-twin-based monitoring for an industrial case study.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Digital Twin Platforms: Microsoft Azure Digital Twins, AWS IoT TwinMaker, NVIDIA Omniverse, Siemens Xcelerator
- Simulation & CAE: ANSYS Twin Builder, Siemens Simcenter, MATLAB/Simulink, OpenFOAM
- CAD: SolidWorks, Autodesk Fusion 360, Siemens NX
- IoT & Middleware: Node-RED, MQTT brokers (Mosquitto), OPC-UA servers
- Data Analysis & AI: Python (NumPy, Pandas, Scikit-learn, TensorFlow), Jupyter Notebook

- Visualisation & AR: Unity, Unreal Engine, Microsoft HoloLens (conceptual exposure)

Suggested Reading

Reference Books

- Boschert, S., & Rosen, R. (2016). "Digital Twin — The Simulation Aspect." In: Mechatronic Futures. Springer.
- Rasheed, A., San, O., & Kvamsdal, T. (2020). "Digital Twin: Values, Challenges, and Enablers from a Modeling Perspective." IEEE Access, Vol. 8.

Additional Resources

- NPTEL — Digital Twin and Industry 4.0 courses (IIT Kharagpur, IIT Madras). [https://onlinecourses.nptel.ac.in/elearning/preview/noc26_ge04](https://onlinecourses.nptel.ac.in/e-learning/preview/noc26_ge04)
- Coursera — Digital Twin Technology. [https://www.udemy.com/course/digital-twin](https://www.udemy.com/course/digital-twin-technology-for-smart-manufacturing)[technology-for-smart-manufacturing.](https://www.udemy.com/course/digital-twin-technology-for-smart-manufacturing)

DLI Course Mapped

Building Digital Twins for Physical AI with NVIDIA Omniverse

DLI Learning Path

- Digital Twins for Physical AI: https://www.nvidia.com/en-us/learn/learning-path/digital-twins/

Embedded Systems for Intelligent Mechanical Applications

(As per Choice Based Credit System)	
Course Code: 26MDE5211	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Fundamentals of Electronics, Digital Logic and Programming Concepts	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to provide students with foundational and applied knowledge of embedded systems for intelligent mechanical applications. The course integrates embedded hardware, communication protocols, control systems, and automation concepts to design smart mechanical systems used in industrial and mechatronic applications.

Course Objectives

Students will be able to:

- Gain knowledge of embedded systems and intelligent mechanical applications.
- Understand microcontroller architecture, interfacing techniques, and embedded control systems.
- Apply communication protocols and real-time embedded concepts in smart automation systems.
- Develop embedded system models and hardware-software integrated solutions.
- Analyze intelligent embedded applications used in robotics, automation, and condition monitoring systems.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the fundamentals of embedded systems and intelligent	L2

CO	Course Outcome	BTL
	mechanical applications.	
CO2	Apply embedded interfacing and control techniques using microcontrollers and peripheral devices.	L3
CO3	Analyze communication protocols and real-time embedded system concepts for automation applications.	L4
CO4	Apply embedded system modeling and hardware-software integration techniques for intelligent systems.	L3
CO5	Analyze embedded applications in robotics, automation, and smart mechanical systems.	L4

Broad Course Description

This course introduces embedded systems for intelligent mechanical applications with emphasis on microcontroller-based design, interfacing, communication, and automation systems. The course covers embedded hardware fundamentals, control systems,

communication protocols, real-time applications, and intelligent monitoring systems used in modern mechanical and mechatronic industries. Students gain practical understanding of hardware-software integration and smart automation technologies for industrial

Detailed Course Syllabus

Course Modules

Module 1: Introduction to Intelligent Embedded Systems (9 Hours)

Introduction to Embedded Systems, Intelligent Mechanical Applications, Sensors and Actuators for Smart Systems, Modular Embedded System Design, Microcontroller Fundamentals, Features of Modern Microcontrollers, MSP430 Architecture and Programming Basics.

Engineering Applications: Smart Embedded Monitoring Systems, Sensor-Based Mechanical Automation, Intelligent Embedded Controllers for Industrial Applications.

Module 2: Embedded Interfacing and Control Systems (9 Hours)

Physical Interfacing of Switches, LEDs and Displays, Digital Input and Output Interfacing, Interrupts and Timer Systems, Pulse Width Modulation (PWM), ADC and DAC Interfacing, Embedded Control for Intelligent Mechanical Systems.

Engineering Applications: Motor Speed Control Systems, Embedded Display and Monitoring Units, Intelligent Actuator Control Systems.

Module 3: Communication and Real-Time Embedded Applications (9 Hours)

Serial Communication Protocols: UART, SPI and I2C, Low Power Embedded Systems, Signal Measurement and Processing, Embedded C Programming, Introduction to Real-Time Embedded Systems, Smart Monitoring and Automation Applications.

Engineering Applications: Real-Time Industrial Automation, Smart Sensor Networks, Embedded Communication Systems for Intelligent Machines.

Module 4: Intelligent System Design and Optimization (9 Hours)

Embedded System Modeling, Finite State Machine with Datapath (FSMD) Design, Hardware-Software Integration, Circuit Prototyping Techniques, Embedded System Optimization for Mechanical Applications.

Engineering Applications: Intelligent Embedded Product Design, Hardware-Software Co-Design for Mechanical Systems, Embedded Optimization in Automation Systems.

Module 5: Smart Mechanical System Applications (9 Hours)

Embedded Applications in Intelligent Mechanical Systems, Smart Sensors and Automation, Condition Monitoring Systems, Embedded Control in Robotics and Mechatronics, Mini Project on Intelligent Embedded Mechanical Application.

Engineering Applications: Robotics and Mechatronic Systems, Predictive Maintenance Systems, Smart Industrial Automation Platforms.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	1	–	2	–	–	–	–	–	–	–	2
CO2	1	–	2	–	1	–	–	–	–	–	–	–	–
CO3	2	3	1	–	1	–	–	–	–	2	–	–	–
CO4	1	–	–	–	3	–	–	–	–	–	–	–	–
CO5	2	3	1	–	1	–	–	–	–	–	–	–	**3**

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

- Analysis of embedded system architecture and evaluation of sensor-actuator integration for intelligent mechanical applications.
- Evaluation of embedded interfacing and control techniques and analysis of real-time embedded control systems.
- Analysis of embedded communication protocols and reflection on real-time automation systems used in industrial applications.
- Evaluation of hardware-software integration methodologies and analysis of embedded optimization techniques for intelligent systems.
- Analysis of smart embedded applications in robotics and automation and reflection on intelligent mechanical system implementation.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Code Composer Studio (CCS)
- MSP430 LaunchPad
- Proteus Simulation Software
- MATLAB / Simulink
- Embedded C Programming Tools

Suggested Reading

Reference Books

- Frank Vahid and Tony Givargis, Embedded System Design, Wiley.
- David E. Simon, An Embedded Software Primer, Pearson.
- Mohammad Ali Mazidi, Microcontroller and Embedded Systems, Pearson.
- W. Bolton, Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering, Pearson.
- Robert H. Bishop, The Mechatronics Handbook, CRC Press.

Additional Resources

- NPTEL Courses on Embedded Systems
- Texas Instruments MSP430 Documentation
- ARM Cortex-M Embedded Tutorials
- IEEE Research Papers on Intelligent Embedded Systems
- Industrial Automation and Robotics Learning Resources

DLI Course Mapped

Fundamentals of Deep Learning for Embedded Systems
https://learn.nvidia.com/

DLI Learning Path

- AI for Embedded Mechanical Systems
- Edge AI and Intelligent Sensing
- Real-Time Embedded Control with AI

Advanced Machine Design

(As per Choice Based Credit System)	
Course Code: 26MDE5212	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Machine Design, Strength of Materials, Theory of Elasticity, Mechanical Engineering Design Fundamentals	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop advanced competency in machine component design considering fatigue, fracture, stress-life behavior, crack growth, and surface failure mechanisms for reliable and safe mechanical system design.

To provide postgraduate students in Design Engineering with an in-depth understanding of

Course Objectives

Students will be able to:

- Understand advanced failure theories and fatigue behavior in machine design.
- Analyze stress-life and strain-life approaches for fatigue design applications.
- Apply Linear Elastic Fracture Mechanics (LEFM) concepts for crack growth and fracture analysis.
- Evaluate fatigue behavior under variable amplitude loading conditions.
- Investigate surface failure mechanisms and their influence on machine component reliability.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the stress–life (S–N) approach, fatigue failure mechanisms, and the factors affecting the fatigue strength of machine components.	L2
CO2	Analyze crack growth and fracture behavior of machine components	L4

CO	Course Outcome	BTL
	using LEFM concepts.	
CO3	Apply cumulative damage rules and cycle-counting methods to estimate fatigue life under variable-amplitude loading.	L3
CO4	Apply friction, adhesive wear, abrasive wear, and lubrication concepts to characterize surface degradation of mating machine elements.	L3
CO5	Analyze corrosion wear, Hertzian contact stresses, surface fatigue, and pitting failure to support wear-resistant design of machine elements.	L4

Broad Course Description

This course introduces advanced concepts in machine design focusing on fatigue, fracture mechanics, crack propagation, cumulative damage theories, and surface failure mechanisms in engineering components. The course emphasizes the design of reliable mechanical systems subjected to static, cyclic, and variable loading conditions.

Learners will gain exposure to:

- Mechanical failure theories
- Fatigue and fracture behavior
- Stress-life and strain-life methods
- Linear Elastic Fracture Mechanics (LEFM)

Detailed Course Syllabus

Course Modules

Module 1: Stress–Life (S–N) Approach (9 Hours)

S–N curves, statistical nature of fatigue test data, mean stress effects, factors influencing S–N behavior, S–N curve approximations, constant life diagrams, and fatigue life estimation using the S–N approach. Strain–Life (ε–N) Approach: Cyclic stress–strain behavior, strain-controlled test methods, strain–life fatigue properties, mean stress effects, and life estimation by the ε–N approach.

Engineering Applications: *Springs, crankshafts, connecting rods, turbine blades, suspension systems.*

Module 2: LEFM Approach (9 Hours)

LEFM concepts, crack-tip plastic zone, fracture toughness, fatigue crack growth, mean stress effects, crack growth life estimation. Notches and Their Effects: Stress and strain concentrations and gradients, S–N approach for notched members, mean stress effects and Haigh diagrams, notch strain analysis, strain–life approach, Neuber's rule, Glinka's rule, applications of fracture mechanics to crack growth at notches.

Engineering Applications: *Aircraft structures, welded joints, pressure vessels, gear root failures, structural crack assessment.*

Module 3: Fatigue from Variable Amplitude Loading (9 Hours)

Spectrum loads and cumulative damage, damage quantification and the concepts of damage fraction and accumulation, cumulative damage theories, load interaction and sequence effects, cycle counting methods, life estimation using stress–life approach.

Engineering Applications: *Automotive loading cycles, railway axles, offshore structures, wind turbine systems, heavy equipment.*

Module 4: Surface Failure – Part I (9 Hours)

Introduction to surface failure mechanisms, surface geometry and roughness characterization, mating surfaces and contact conditions, friction mechanisms and coefficients, adhesive wear and its governing parameters, abrasive wear mechanisms and material removal rates, and influence of lubrication regimes on surface degradation.

Engineering Applications: *Journal and sliding bearings (lubrication regimes), brake and clutch friction materials, piston ring–cylinder liner wear, cutting-tool and die wear.*

Module 5: Surface Failure – Part II (9 Hours)

Corrosion wear and its interaction with mechanical loading, surface fatigue under spherical contact (Hertzian contact stresses), cylindrical and general contact configurations, dynamic contact stresses under rolling and sliding conditions, surface fatigue strength and pitting failure, and design guidelines for wear-resistant surface treatments and coatings.

Engineering Applications: *Bearings, gears, cams, rolling contact elements, tribological systems*

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	3	–	–	2	–	–	–	–	–	–	–	3
CO2	2	3	–	–	1	–	–	–	–	–	–	–	3
CO3	2	3	–	–	1	–	–	–	–	–	–	–	3
CO4	2	2	–	–	2	–	–	–	–	–	–	–	2
CO5	2	2	–	–	2	–	–	–	–	–	–	–	2

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand how Artificial Intelligence and machine learning can be applied to predict fatigue life, optimize component design, and detect failure patterns in

advanced machine design.

Example Activities:

- Develop a machine-learning model to predict fatigue life of a machine component from stress-life (S-N) data.
- Apply AI-assisted design optimization to minimize weight while satisfying fatigue and strength constraints.
- Simulate AI-based crack growth prediction using LEFM-generated datasets.
- Evaluate machine-learning classifiers for surface failure mode identification such as wear, pitting, and spalling.
- Compare conventional design-for-fatigue methods with AI-assisted predictive design approaches.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Suggested Reading

Primary Textbooks

- Ralph I. Stephens, Ali Fatemi, Robert R. Stephens, and Henry O. Fuchs, Metal Fatigue in Engineering, John Wiley, New York, Second Edition, 2001.
- Jack A. Collins, Failure of Materials in Mechanical Design, John Wiley, New York, 1992.

Reference Books

- S. Suresh, Fatigue of Materials, Second Edition, Cambridge University Press, Cambridge, U.K., 1998.
- Julie A. Benantine, Fundamentals of Metal Fatigue Analysis, Prentice-Hall, 1990.
- ASM Metals Handbook, Fatigue and Fracture, Vol. 19, 2002.

Additional Resources

- NPTEL – Fatigue and Fracture Mechanics
- ASM International Learning Resources
- ANSYS Fatigue Analysis Tutorials
- MIT OpenCourseWare – Fracture Mechanics
- ASTM Standards for Fatigue Testing

DLI Course Mapped

Applications of AI for Predictive Maintenance
https://learn.nvidia.com/

DLI Learning Path

- AI-Assisted Failure Prediction
- Digital Fatigue Analysis
- Smart Structural Health Monitoring
- Intelligent Mechanical Design Systems

Micro and Nano Electro-Mechanical Systems (MEMS/NEMS)

(As per Choice Based Credit System)	
Course Code: 26MDE5213	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Solid Mechanics, Material Science, Basics of Semiconductor Fabrication and Microfabrication Techniques	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop advanced knowledge of micro- and nano-electromechanical systems (MEMS/NEMS), covering scaling laws, fabrication processes, sensor design, and characterisation techniques. The course enables postgraduate learners to design, analyse, and evaluate MEMS/NEMS-based devices for applications in sensing, actuation, and miniaturised engineering systems.

Course Objectives

Students will be able to:

- Understand the fundamentals of MEMS/NEMS technology, scaling laws, and material properties relevant to micro/nano-scale devices.
- Analyse fabrication processes including oxidation, physical and chemical vapour deposition, lithography, and micromachining techniques.
- Apply knowledge of sensor design, signal conditioning, and interfacing techniques for MEMS-based sensing systems.
- Evaluate characterisation methods for MEMS/NEMS devices and assess their performance, reliability, and failure mechanisms.
- Design and critically assess MEMS/NEMS solutions for real-world industrial applications across automotive, biomedical, aerospace, and IoT domains.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the fundamentals of MEMS/NEMS technology, scaling laws, and material properties governing micro/nano-scale device behaviour.	L2
CO2	Analyze MEMS fabrication techniques including oxidation, physical and chemical vapour deposition, and lithography processes.	L4
CO3	Analyze micromachining processes (surface, bulk, and advanced techniques) used for the fabrication of MEMS/NEMS structures.	L4
CO4	Apply sensor design principles and interfacing techniques for MEMS-based sensing and actuation systems.	L3
CO5	Analyze characterisation methods, performance evaluation, reliability, and industrial applications of MEMS/NEMS devices.	L4

Broad Course Description

Micro and Nano Electro-Mechanical Systems (MEMS/NEMS) is a professional elective course for M.Tech. Design Engineering students. The course provides a comprehensive treatment of the science, engineering, and technology of miniaturised electro-mechanical systems at the micro and nano scales. Beginning with fundamental concepts — scaling laws, material properties at reduced dimensions, and the MEMS landscape — the course systematically progresses through the major fabrication technologies: thermal oxidation, physical vapour deposition (PVD), chemical vapour deposition (CVD), photolithography, and advanced lithographic techniques (e-beam, deep UV, nanoimprint).

A dedicated module covers micromachining in depth — surface micromachining, bulk micromachining (wet and dry etching), LIGA, and emerging nano-fabrication methods. The course then addresses MEMS sensors and actuators — their transduction principles, signal conditioning, readout electronics, and interfacing with external systems. The final module covers device characterisation (optical, electron microscopy, profilometry, electrical testing), reliability analysis, packaging, and real-world applications spanning automotive, biomedical, aerospace, telecommunications, energy harvesting, and IoT. AI tools are integrated throughout for simulation assistance, literature analysis, and critical evaluation of device performance.

Detailed Course Syllabus

Course Modules

Module 1: Introduction to MEMS/NEMS and Material Properties (9 Hours)

Introduction to MEMS and NEMS: definition, evolution, and comparison with macro-scale devices.

Scaling laws: geometric, electrostatic, thermal, and fluidic scaling at micro/nano dimensions. Material properties at micro/nano scale: mechanical (Young's modulus, residual stress, fatigue), electrical (piezoresistivity, piezoelectricity), and thermal properties. Materials for MEMS: single-crystal silicon, polysilicon, silicon dioxide and nitride, metals, polymers (SU-8, PDMS), and piezoelectric materials (PZT, AlN, ZnO). Substrates and wafer preparation: crystal orientation and doping. NEMS concepts: carbon nanotubes, graphene, and nanowires.

Engineering Applications: Automotive MEMS pressure sensors using piezoresistive silicon. Biomedical MEMS: microcantilever biosensors for disease detection. Consumer electronics: MEMS accelerometers and gyroscopes in smartphones. Aerospace: high-temperature SiC MEMS pressure sensors for engine monitoring. NEMS-based mass sensors for chemical/biological agent detection.

Module 2: MEMS Sensor Fabrication — Oxidation, Deposition, and Lithography (9 Hours)

Thermal oxidation: dry and wet oxidation, Deal–Grove model, and applications in MEMS. Thin-film deposition: physical vapour deposition (evaporation, sputtering) and chemical vapour deposition (LPCVD, PECVD); comparison of film quality, conformality, and stress. Lithography: photoresist processing (spin coating, exposure, development), optical lithography (contact, proximity, projection), resolution limits (Rayleigh criterion, numerical aperture, depth of focus), and mask design. Advanced lithography: DUV, EUV, electron beam, and nanoimprint lithography.

Engineering Applications: Thermal oxide as gate dielectric and sacrificial layer in surface micromachined accelerometers. Sputtered AlN thin films for piezoelectric MEMS energy harvesters. PECVD silicon nitride as passivation layer for MEMS packaging. E-beam lithography for sub-100 nm NEMS resonator fabrication. DUV lithography for high-volume MEMS inertial sensor production.

Module 3: MEMS Sensor Fabrication — Micromachining Techniques (9 Hours)

Bulk micromachining: isotropic and anisotropic wet etching (KOH, TMAH), crystal-orientation dependence, and etch-stop techniques. Dry etching: plasma etching, RIE, and DRIE (Bosch process). Surface micromachining: process sequence, sacrificial layer release, and stiction with anti-stiction techniques. LIGA process for high-aspect-ratio microstructures. Wafer bonding (anodic, fusion, eutectic) and SOI-based MEMS fabrication. Overview of emerging nano-fabrication: FIB, ALD, and self-assembly.

Engineering Applications: KOH-etched silicon diaphragms for pressure sensors. DRIE-fabricated comb-drive actuators for optical MEMS (micro-mirrors). Surface micromachined polysilicon MEMS accelerometers (Analog Devices ADXL series). LIGA-fabricated nickel micro-gears for micro-turbines. SOI-MEMS inertial sensors for automotive and aerospace applications. Anodic bonding for hermetic MEMS packaging.

Module 4: Sensors and Interfacing Techniques: (9 Hours)

MEMS sensing and actuation principles: piezoresistive, capacitive, piezoelectric, resonant, and thermal transduction. MEMS sensors: pressure sensors, accelerometers, and gyroscopes, with an overview of flow, gas, and biosensors. MEMS actuators: electrostatic (parallel plate, comb drive), piezoelectric, and thermal bimorph actuators. Signal conditioning: Wheatstone bridge, charge amplifiers, and capacitance-to-voltage converters. Noise sources in MEMS and noise-floor estimation. Interfacing with microcontrollers using I^2C, SPI, and analogue interfaces; sensor calibration and temperature compensation.

Engineering Applications: Piezoresistive MEMS pressure sensor with Wheatstone bridge readout for automotive tyre pressure monitoring (TPMS). Capacitive MEMS accelerometer with CMOS-

integrated readout for airbag deployment systems. Piezoelectric MEMS energy harvester with AC-DC power conditioning circuit. MEMS gyroscope with digital SPI interface for drone flight stabilisation. MEMS gas sensor array with microcontroller-based pattern recognition for air quality monitoring.

Module 5: Characterisation, Reliability, and Applications of MEMS/NEMS (9 Hours)

Characterisation techniques: optical microscopy, SEM, AFM, white-light interferometry, and stylus profilometry. Mechanical characterisation (nanoindentation, micro-tensile and bulge testing, resonance frequency measurement) and electrical characterisation (I-V and C-V measurements). Performance metrics: sensitivity, resolution, bandwidth, dynamic range, linearity, and noise floor. Reliability and failure analysis: fatigue, stiction, wear, creep, and dielectric charging. MEMS packaging: wafer-level, hermetic, and vacuum packaging. Industrial applications (automotive, biomedical, aerospace, RF, energy, IoT) and future trends (NEMS resonators, AI-driven MEMS design).

Engineering Applications: AFM-based characterisation of MEMS cantilever spring constants. Nanoindentation of thin-film mechanical properties for MEMS structural design. Reliability testing of capacitive MEMS switches for 5G RF applications. Wafer-level vacuum packaging of MEMS gyroscopes for automotive-grade reliability. Lab-on-chip MEMS platforms for point-of-care diagnostics. MEMS energy harvesters for IoT wireless sensor nodes.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	–	–	2	–	–	–	–	–	–	–	2
CO2	2	3	–	–	1	–	–	–	–	–	–	–	–
CO3	2	3	–	–	1	–	–	–	–	–	–	–	3
CO4	3	–	3	–	1	–	–	–	–	–	–	1	–
CO5	2	3	1	–	1	–	–	–	–	–	–	–	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Understand how Artificial Intelligence and machine learning support the design, fabrication-process optimization, and reliability prediction of MEMS/NEMS devices.

Example Activities:

- Develop a machine-learning model to predict the resonant frequency or sensitivity of a MEMS sensor from geometric and material parameters.
- Simulate AI-assisted optimization of MEMS device geometry for improved performance.
- Evaluate AI-based defect detection in MEMS fabrication process data.
- Analyse machine-learning-based reliability prediction for MEMS/NEMS devices under cyclic loading.

- Compare conventional analytical MEMS design models with AI-assisted surrogate models.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- MEMS Simulation: COMSOL Multiphysics, IntelliSuite, CoventorMP, ANSYS
- CAD & Layout: L-Edit (Tanner EDA), KLayout, Cadence Virtuoso
- Process Simulation: Silvaco ATHENA/ATLAS, Synopsys Sentaurus TCAD
- Data Analysis & AI: Python (NumPy, SciPy, Scikit-learn, TensorFlow), MATLAB

- Characterisation Analysis: ImageJ (SEM/AFM image analysis), Gwyddion (AFM data)

Suggested Reading

Reference Books

- Maluf, N. & Williams, K. (2004). "An Introduction to Microelectromechanical Systems Engineering" (2nd ed.). Artech House. ISBN: 978-1580535908.
- Liu, C. (2011). "Foundations of MEMS" (2nd ed.). Pearson. ISBN: 978-0132497367.

Additional Resources

- NPTEL — MEMS and Microsystems (IIT Bombay, IIT Madras).
- Coursera — Micro Electromechanical Systems. [https://www.coursera.org/learn/micro-](https://www.coursera.org/learn/micro-electromechanical-systems)[electromechanical-systemsmodules](https://www.coursera.org/learn/micro-electromechanical-systems)

DLI Course Mapped

Fundamentals of Deep Learning: [https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-FX-01+V1](https://learn.nvidia.com/courses/course-detail?course_id=course-v1%3ADLI+S-FX-01+V1)

DLI Learning Path

- Deep Learning for Science and Engineering: https://www.nvidia.com/en-us/on-demand/deep-learning-for-science-and-engineering/
- Physics-Informed Machine Learning for MEMS/NEMS Design
- AI-Assisted Micro-Fabrication Process Optimization

Non-Destructive Testing and Structural Health Evaluation

(As per Choice Based Credit System)	
Course Code: 26MDE5214	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Mechanics of Materials, Structural Analysis, Engineering Materials	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course develops in students a rigorous understanding of non-destructive testing (NDT) methods and structural health monitoring (SHM) systems used to evaluate material integrity and structural performance without causing damage. Students gain practical exposure to ultrasonic, radiographic, magnetic, eddy-current, and acoustic emission techniques, and learn how sensor networks, signal processing, and AI-powered inspection tools are applied to ensure the safety and reliability of engineering structures.

Course Objectives

Students will be able to:

- Understand the fundamental principles, physics, and governing standards of various NDT methods.
- Apply ultrasonic, radiographic, magnetic particle, dye-penetrant, eddy-current, acoustic emission, and thermographic techniques to structural inspection.
- Analyse signals, waveforms, and imaging data obtained from NDT instruments to evaluate material and structural integrity.
- Understand structural health monitoring (SHM) concepts including sensor networks, data acquisition, and continuous monitoring architectures.
- Apply damage detection, prognosis, and remaining-life estimation methodologies to civil, mechanical, and aerospace structures.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the fundamental principles, classifications, governing standards, defect types, Probability of Detection (POD), and safety regulations relevant to non-destructive testing.	L2
CO2	Apply contact and surface NDT techniques (VT, LPT, MT, ECT, rebound hammer, half-cell potential, and GPR) to evaluate structural components.	L3
CO3	Apply volumetric NDT methods (UT/PAUT/TOFD, RT/DR, CT, AE, and IRT) for internal defect characterisation in engineering structures.	L3
CO4	Apply piezoelectric, fibre Bragg grating, and MEMS sensor-based SHM techniques to interpret Lamb wave and vibration-based damage indices for continuous structural monitoring.	L3
CO5	Analyze damage prognosis, remaining useful life (RUL), and fitness-for-service (ASME/API 579) assessments, and apply AI/ML-based automated inspection methods (CNN defect detection, digital twin, wavelet/HHT signal processing) in NDT and SHM.	L4

Broad Course Description

This course provides a comprehensive study of non-destructive evaluation (NDE) and structural health monitoring as applied in modern engineering practice. Students study the physical principles of wave propagation, electromagnetic phenomena, radiation interaction, and thermal diffusion that underlie the major NDT families, learning how each technique is calibrated, performed, and interpreted against ASTM, ASME, and IS codes.

The SHM strand equips students with the knowledge to design sensor networks, process dynamic structural data, and implement guided-wave, vibration-based, and fibre-optic monitoring systems for bridges, buildings, pressure vessels, aircraft structures, and rotating machinery.

The course culminates in an introduction to AI-assisted NDT, including convolutional neural networks for radiographic and thermographic image analysis, GPU-accelerated defect detection, and digital twins for predictive maintenance — positioning graduates at the forefront of smart structural assessment technology.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Non-Destructive Testing (9 Hours)

Introduction to NDT: definition, need, scope, and comparison with destructive testing. Classification

of NDT methods: surface, volumetric, and radiation-based techniques. NDT codes and standards: overview of ASME Sec. V, ASTM E-series, and IS 2595. Material defects: types (cracks, voids, inclusions, delaminations, corrosion, fatigue damage), origin, and significance. General inspection procedure: planning, calibration, scanning, reporting, and acceptance criteria. Probability of Detection (POD) and performance qualification. Personnel certification (ASNT SNT-TC-1A, ISO 9712) and radiation safety.

Engineering Applications: Pre-service and in-service inspection of pressure vessels, weld quality assurance in fabrication shops, bridge deck condition assessment, nuclear component surveillance.

Module 2: Contact and Surface NDT Methods (9 Hours)

Visual testing (VT): direct optical, borescope, and remote video inspection. Liquid penetrant testing (LPT): fluorescent and colour-contrast methods, procedure, and interpretation per ASTM E165. Magnetic particle testing (MT): magnetisation techniques (yoke, prod), wet fluorescent and dry methods, demagnetisation, and interpretation per ASTM E709. Eddy current testing (ECT): impedance plane analysis, absolute and differential probes, and applications in tube and weld inspection. Concrete and RCC assessment: rebound hammer, ultrasonic pulse velocity, and half-cell potential. Ground Penetrating Radar (GPR): principles, antenna selection, and interpretation of scans for rebar cover and void detection.

Engineering Applications: In-service RCC bridge deck inspection, aircraft fuselage skin crack detection, heat-exchanger tube assessment, pipeline external corrosion survey.

Module 3: Volumetric NDT Methods (9 Hours)

Ultrasonic testing (UT): longitudinal, shear, and surface waves; beam geometry, transducers, and couplants; pulse-echo, through-transmission, and TOFD techniques. Phased Array Ultrasonic Testing (PAUT): electronic beam steering and S-scan imaging. Radiographic testing (RT): X-ray and gamma-ray principles, exposure charts, film radiography, and digital radiography (DR/CR); overview of computed tomography (CT). Acoustic emission (AE) testing: source location and Kaiser and Felicity effects. Infrared thermography (IRT): active (lock-in and pulsed) methods for delamination detection and passive hot-spot monitoring.

Engineering Applications: Weld flaw sizing in power plant piping, composite aircraft panel delamination mapping, wind turbine blade thermographic survey, in-situ pressure vessel AE monitoring.

Module 4: Structural Health Monitoring — Principles and Systems (9 Hours)

Introduction to SHM: objectives, damage identification levels (Rytter hierarchy), and comparison with scheduled NDT inspection. SHM system architecture: sensing, data acquisition, data management, feature extraction, and decision-making layers. Sensor technologies: piezoelectric (PZT) transducers, MEMS accelerometers, fibre Bragg grating (FBG) sensors, and strain gauges — selection criteria. Guided-wave (Lamb wave) SHM: symmetric and anti-symmetric modes, dispersion curves, and pitch-catch paths. Vibration-based damage detection: natural frequency shift, mode shape curvature, and damage index methods. Continuous monitoring with wireless sensor networks and IoT-enabled SHM platforms.

Engineering Applications: Real-time bridge monitoring (Bandra–Worli Sea Link), wind turbine drivetrain vibration analysis, dam seepage and settlement monitoring, aircraft fuselage fatigue tracking.

Module 5: Data Analysis, Damage Prognosis, and AI in NDT/SHM (9 Hours)

Signal processing for NDT/SHM: FFT, STFT, wavelet transform, and Hilbert–Huang transform (HHT) for feature extraction from ultrasonic, AE, and vibration signals. Machine learning for damage identification: statistical pattern recognition and novelty detection (PCA, Mahalanobis distance), supervised classification (SVM, Random Forest), and unsupervised clustering. Deep learning in NDT: CNN-based defect detection in radiographic and CT images. Digital twins for structural integrity: FE model updating and physics-informed neural networks. Damage prognosis and Remaining Useful Life (RUL): Paris–Erdogan crack growth law and Bayesian updating. Fitness-for-service (FFS) assessment: API 579-1/ASME FFS-1 framework.

Engineering Applications: Automated X-ray weld inspection using CNN (automotive/oil & gas), predictive maintenance for offshore jacket platforms, GPU-accelerated anomaly detection in power plant SHM networks, AI-assisted corrosion assessment for ageing aircraft structures.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	–	–	2	2	2	–	–	–	–	–	–	–
CO2	1	2	–	2	1	–	–	–	–	–	–	–	3
CO3	2	–	3	2	1	–	–	–	–	–	–	–	2
CO4	2	3	3	2	1	2	–	–	–	–	–	2	3
CO5	2	3	3	2	3	–	–	–	–	–	–	–	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

Example: Train a lightweight CNN in Python (PyTorch/Keras) to classify defect vs. no-defect radiographic images from the GDXray or DAGM benchmark dataset:

- Load and preprocess a labelled NDT image dataset (resize, normalise, augment).
- Define a 3-layer CNN: Conv2D → ReLU → MaxPool (×2) → Flatten → Dense → Softmax.
- Train the model and plot training/validation accuracy curves.
- Evaluate on a held-out test set; display the confusion matrix and ROC curve.
- Visualise Grad-CAM activation maps to identify which image regions the network uses as defect evidence.
- Discuss how GPU parallelism (CUDA) accelerates the matrix-multiply operations inside each convolution layer — connecting to the NVIDIA DLI mapped course.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's

Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- NDT Software: TOMOVIEW (PAUT data analysis), WeldSight, MISTRAS AEwin
- Signal Processing: MATLAB Signal Processing Toolbox, Python (SciPy, PyWavelets, MNE)
- AI / ML: PyTorch, TensorFlow/Keras, NVIDIA TAO Toolkit, NVIDIA Triton Inference Server
- SHM Platforms: SAP2000 (modal analysis), OpenSees, Seismosoft SeismoSignal
- Visualisation: NVIDIA Nsight Systems, ParaView, FLIR ResearchIR

Suggested Reading

Reference Books

- Shull, P.J. (2002). Nondestructive Evaluation: Theory, Techniques, and Applications.

- Marcel Dekker, New York.
- Bray, D.E. & Stanley, R.K. (1997). Nondestructive Evaluation: A Tool for Design, Manufacturing and Service. CRC Press.
- Giurgiutiu, V. (2007). Structural Health Monitoring with Piezoelectric Wafer Active Sensors. Academic Press.
- Rose, J.L. (2014). Ultrasonic Guided Waves in Solid Media. Cambridge University Press.

Additional Resources

- NOC: Non-Destructive Testing of Welds — IIT Madras / NPTEL (https://nptel.ac.in)
- Structural Health Monitoring — IIT Bombay / NPTEL (https://nptel.ac.in)
- ASNT e-Handbook of Nondestructive Testing (https://www.asnt.org)
- CSIR-SERC NDT Resources (https://www.serc.res.in)

DLI Course Mapped

Computer Vision for Industrial Inspection [https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-MF-01+V2](https://learn.nvidia.com/courses/course-detail?course_id=course-v1%3ADLI+C-MF-01+V2)

DLI Learning Path

- AI-Assisted Defect Detection and Classification
- Computer Vision for Structural Inspection
- Digital Twin-Based Structural Health Monitoring

Industrial Hydraulic and Pneumatic Systems

(As per Choice Based Credit System)	
Course Code: 26MDE5215	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Fluid Mechanics, Engineering Mechanics, Manufacturing Processes	
Course Type: Skill Enhancement Course (SEC)	**Hours/Week:** 04 **Total Hours:** 60 Hrs – 60 Hrs (Practical) **Credits:** 02
L – T – P – J: 0 – 0 – 4 – 0	

Course Vision

This course aims to develop practical competencies in industrial hydraulic and pneumatic systems through hands-on training using Bosch Rexroth industrial automation platforms. The course emphasizes fluid power technologies, electro-hydraulic systems, electro-pneumatic control, industrial automation, and smart manufacturing applications widely used in modern industries.

Course Objectives

Students will be able to:

- Understand the principles and components of hydraulic and pneumatic systems.
- Design and analyze industrial hydraulic circuits and pneumatic control systems.
- Develop electro-hydraulic and electro-pneumatic automation solutions.
- Integrate sensors, actuators, and programmable controllers in fluid power applications.
- Apply Industry 4.0 and intelligent automation concepts in industrial fluid power systems.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Identify and operate hydraulic and pneumatic components used in industrial systems.	L3
CO2	Develop hydraulic and pneumatic circuits for industrial automation applications.	L3
CO3	Analyze electro-hydraulic and electro-pneumatic control systems.	L4

CO	Course Outcome	BTL
CO4	Implement PLC-based fluid power automation systems.	L4
CO5	Design intelligent fluid power solutions for smart manufacturing environments.	L5

Broad Course Description

This Skill Enhancement Course focuses on industrial fluid power technologies using Bosch Rexroth Innovation Lab infrastructure. The course provides extensive hands-on training in hydraulic systems, pneumatic systems, electro-hydraulics, electro-pneumatics, PLC integration, sensor-based automation, and Industry 4.0 applications.

Students will work with industrial training kits, hydraulic power packs, pneumatic workstations, PLC controllers, sensors, actuators, and industrial automation modules used in manufacturing, robotics, machine tools, process industries, and smart factories. The course adopts a laboratory-intensive approach involving circuit development, troubleshooting, industrial case studies, automation projects, and intelligent manufacturing applications.

Detailed Laboratory / Practical Syllabus

Laboratory Experiments and Practical Activities

This Skill Enhancement Course is conducted entirely in the laboratory (L – T – P – J: 0 – 0 – 4 – 0) and has no theory lectures. The 60 practical hours are organised as fifteen four-hour laboratory sessions on industrial hydraulic, pneumatic, electro-fluid-power and PLC-based automation systems. Each session begins with a short demonstration and is followed by individual or small-group hands-on work; the procedure, results and inferences of every experiment are recorded in a laboratory record / digital portfolio.

Experiments 1–5 (initial skills), 6–10 (intermediate skills) and 11–15 (advanced skills and mini project) correspond to CAT–1, CAT–2 and CAT–3 of the Assessment Scheme respectively.

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
1	**Hydraulic Components Identification and ISO Symbols**	Identify pumps, valves, actuators, accumulators and filters on cut-section models and trainers; draw and interpret ISO 1219 symbols.	CO1	4
2	**Hydraulic Pump Performance Test**	Measure flow, pressure, power and efficiency of a hydraulic pump on the hydraulic trainer and plot its characteristics.	CO1	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
3	**Pneumatic Components and Air Preparation**	Identify pneumatic actuators, valves and the FRL unit; study compressor and cylinder characteristics on the pneumatic trainer.	CO1	4
4	**Directional Control Circuits for Hydraulic Actuators**	Assemble and operate directional-control circuits for single- and double-acting cylinders and a hydraulic motor, including a regenerative circuit.	CO2	4
5	**Pressure and Flow Control Circuits**	Build relief, pressure-reducing, meter-in, meter-out and bleed-off circuits, and sequence and counterbalance circuits; record speed and pressure.	CO2	4
6	**Pneumatic Circuit Development and Simulation**	Design and test pneumatic circuits (speed control, memory, time delay, sequencing) and verify them by simulation.	CO2	4
7	**Electro-Hydraulic Circuits**	Wire solenoid-valve circuits with relays, limit switches and pressure switches to implement cylinder sequencing.	CO3	4
8	**Electro-Pneumatic Sequencing Circuits**	Implement relay-logic electro-pneumatic sequences (e.g., A+ B+ B– A–) and test them under fault conditions.	CO3	4
9	**Simulation and Analysis of Fluid Power Circuits**	Simulate hydraulic and pneumatic circuits in Automation Studio and analyse pressure, flow and actuator response.	CO3	4
10	**Proportional Valve Control and Response Analysis**	Study proportional/servo-valve control of a cylinder; analyse the step response and the effect of controller settings.	CO3	4
11	**PLC Programming for Cylinder Sequencing**	Map inputs/outputs and develop ladder logic (timers, counters) to control pneumatic and hydraulic cylinder sequences.	CO4	4
12	**PLC-Controlled Electro-Pneumatic Automation Station**	Program and commission a pick-and-place or sorting station using sensors and a PLC.	CO4	4
13	**PLC-Controlled Electro-Hydraulic Clamping Circuit and Troubleshooting**	Develop PLC control for a clamp-and-press cycle with pressure switches; inject and diagnose faults.	CO4	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
14	**Sensor Integration and Condition Monitoring**	Integrate pressure, flow and proximity sensors with the PLC and build an HMI/SCADA display for system monitoring.	CO5	4
15	**Industrial Fluid Power Mini Project**	Design, simulate, build and demonstrate an intelligent fluid-power application for smart manufacturing (e.g., material handling, clamping or press).	CO5	4
Total Practical Hours				**60**

Laboratory Resources: Software, Tools and Equipment

- Bosch Rexroth Automation Studio
- FluidSIM (hydraulics and pneumatics) or equivalent circuit-simulation software
- Hydraulic trainer kits (pump, valves, actuators, gauges and flow meters)
- Pneumatic trainer kits with filter–regulator–lubricator (FRL) unit
- Electro-hydraulic and electro-pneumatic trainers with relay panels and solenoid valves
- PLC trainers with ladder-programming software and HMI/SCADA
- Pressure, flow and proximity sensors and limit switches

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	3	–	–	1	–	–	–	–	–	–	–	2
CO2	2	–	3	–	1	–	–	–	–	–	–	–	3
CO3	2	3	2	–	1	–	–	–	–	–	–	–	3
CO4	2	–	3	–	1	–	–	–	–	–	–	–	2
CO5	2	–	3	–	1	–	3	–	–	–	–	2	3

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

Understand the role of Artificial Intelligence in intelligent fluid power systems, predictive maintenance, fault diagnosis, and smart manufacturing automation.

Example Activity:

Develop an AI-assisted predictive maintenance model for a hydraulic system.

- Collect pressure, flow, and vibration data.

- Analyze operational parameters.
- Train an AI-based fault prediction model.
- Identify potential system failures.
- Recommend maintenance actions based on AI-generated insights.

Students shall:

- Evaluate AI-generated maintenance recommendations.
- Compare AI predictions with actual system behavior.
- Assess reliability of intelligent monitoring systems.
- Analyze limitations of AI-assisted diagnostics.
- Reflect on human expertise in industrial automation decision-making.

Assessment Scheme

Skill Enhancement Course (Practical)

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Experiments 1–5	CO1 / CO2 (L1–L2)	20	Fundamental understanding. Quiz / Demonstration / Assignment / Concept Test / Viva
CAT–2 – Apply	Experiments 6–10	CO2 / CO3 (L2–L3)	20	Application of skills. Hands-on Task / Practical Exercise / Problem Solving / Software Activity / Lab Task
CAT–3 – Analyze / Create	Experiments 11–15	CO3 / CO4 / CO5 (L3–L6)	20	Analysis, creation and application. Mini Project / Case Study / Design Task / Practical Demonstration / Presentation
Continuous Skill Assessment	Entire Course	As applicable	20	Practical Performance / Technical Assignment / Activity
Final Skill Demonstration	Entire Course	As applicable	20	Practical Demonstration / Viva / Project Presentation
Total CIA			**100**	**No SEE**

Suggested Reading

Reference Books

- Peter Rohner, Fluid Power Logic Circuit Design, McGraw Hill.
- S.R. Majumdar, Oil Hydraulic Systems: Principles and Maintenance, McGraw Hill.

- S.R. Majumdar, Pneumatic Systems: Principles and Maintenance, McGraw Hill.

Additional Resources

- Bosch Rexroth Learning Portal
- Bosch Rexroth Industrial Automation Manuals
- FluidSIM Learning Resources
- Siemens PLC Training Modules
- NPTEL – Industrial Automation

DLI Course Mapped

Fundamentals of Accelerated Computing for Industrial Automation
https://learn.nvidia.com/

DLI Learning Path

- AI for Industrial Automation
- Smart Manufacturing Systems
- Industrial IoT Fundamentals
- Predictive Maintenance using AI

Computational Engineering using MATLAB

(As per Choice Based Credit System)	
Course Code: 26MDE5216	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mathematics, Numerical Methods, Basic Programming Knowledge	
Course Type: Skill Enhancement Course (SEC)	**Hours/Week:** 04 **Total Hours:** 60 Hrs – 60 Hrs (Practical) **Credits:** 02
L – T – P – J: 0 – 0 – 4 – 0	

Course Vision

This course aims to develop computational problem-solving skills using MATLAB for engineering analysis, modeling, simulation, optimization, and data-driven decision-making. The course emphasizes practical implementation of numerical methods and computational techniques widely used in modern engineering design, simulation, manufacturing, and research environments.

Course Objectives

Students will be able to:

- Develop MATLAB programs for engineering computation and problem-solving.
- Apply numerical methods for solving engineering and scientific problems.
- Perform engineering data analysis, visualization, and simulation using MATLAB.
- Develop mathematical models and optimization solutions for engineering applications.
- Utilize MATLAB toolboxes for advanced computational engineering and design studies.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Develop MATLAB programs using built-in functions and programming constructs for engineering applications.	L3
CO2	Apply numerical methods for solving engineering equations and mathematical models.	L3
CO3	Perform engineering data analysis and visualization using MATLAB	L4

CO	Course Outcome	BTL
	tools.	
CO4	Develop simulation and optimization models for engineering systems.	L4
CO5	Create computational engineering solutions for real-world design and manufacturing problems.	L5

Broad Course Description

This Skill Enhancement Course focuses on practical computational engineering applications using MATLAB. The course provides extensive hands-on experience in engineering programming, numerical analysis, scientific computing, simulation, optimization, signal processing, and engineering data analytics.

Students will work on engineering problems from mechanical design, manufacturing, thermal systems, structural analysis, control systems, and intelligent engineering applications. The course integrates computational methods with engineering decision-making and digital engineering workflows.

The course is delivered through laboratory exercises, industrial case studies, simulation assignments, optimization studies, and computational engineering projects.

Detailed Laboratory / Practical Syllabus

Laboratory Experiments and Practical Activities

This Skill Enhancement Course is conducted entirely in the laboratory (L – T – P – J: 0 – 0 – 4 – 0) and has no theory lectures. The 60 practical hours are organised as fifteen four-hour laboratory sessions on MATLAB-based computation, simulation, optimization and data analysis for engineering problems. Each session begins with a short demonstration and is followed by individual or small-group hands-on work; the procedure, results and inferences of every experiment are recorded in a laboratory record / digital portfolio.

Experiments 1–5 (initial skills), 6–10 (intermediate skills) and 11–15 (advanced skills and mini project) correspond to CAT–1, CAT–2 and CAT–3 of the Assessment Scheme respectively.

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
1	**MATLAB Environment and Engineering Calculations**	Explore the Command Window, Editor and Live Editor; perform vector and matrix operations and basic engineering calculations.	CO1	4
2	**Programming Constructs, Functions and File I/O**	Write scripts and user-defined functions using conditional statements and loops; import and export data files (CSV/Excel).	CO1	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
3	**Matrix and Linear Algebra Applications**	Solve linear systems and eigenvalue problems, and apply LU decomposition to truss and vibration problems.	CO1	4
4	**Solution of Nonlinear Equations**	Implement bisection and Newton–Raphson methods; use fzero and fsolve for engineering equations.	CO2	4
5	**Numerical Differentiation, Integration and ODE Solution**	Apply numerical differentiation and integration; solve initial-value problems with ode45 for spring–mass–damper and thermal systems.	CO2	4
6	**Curve Fitting and Interpolation**	Fit and interpolate experimental data using polyfit, splines and the Curve Fitting Toolbox; evaluate the quality of fit.	CO2	4
7	**Engineering Data Import and Processing**	Import experimental and sensor data into tables; clean, filter and pre-process it for analysis.	CO3	4
8	**Statistical Analysis of Engineering Datasets**	Perform descriptive statistics, distribution fitting, hypothesis testing and regression using the Statistics and Machine Learning Toolbox.	CO3	4
9	**2D and 3D Data Visualization**	Create line, scatter, contour and surface plots, subplots and annotated figures for engineering results.	CO3	4
10	**GUI Development using App Designer**	Build an interactive App Designer application for an engineering analysis or design calculation.	CO3	4
11	**Mathematical Model Development and Simulink Modelling**	Develop Simulink models of a mass–spring–damper, DC motor or thermal system and analyse their response.	CO4	4
12	**Simulation of Engineering Control Systems**	Simulate a control system using transfer functions; tune a PID controller and study the step response.	CO4	4
13	**Engineering Optimization using Optimization Toolbox**	Formulate and solve constrained optimization problems (fmincon, ga) such as minimum-weight truss or shaft design.	CO4	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
14	**Machine Learning for Engineering Prediction**	Train and validate regression and classification models; perform predictive analytics on an engineering dataset.	CO5	4
15	**Computational Engineering Mini Project**	Integrate numerical methods, data analysis, simulation and optimization in a mini project; demonstrate it and submit a report.	CO5	4
Total Practical Hours				**60**

Laboratory Resources: Software, Tools and Equipment

- MATLAB with Live Editor
- Simulink
- Optimization Toolbox
- Statistics and Machine Learning Toolbox
- Curve Fitting Toolbox
- App Designer

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	3	–	3	–	–	–	–	–	–	–	–
CO2	3	–	–	–	2	–	–	–	–	–	–	–	2
CO3	2	3	–	2	3	–	–	–	–	–	–	–	–
CO4	2	–	3	–	3	–	–	–	–	–	–	–	3
CO5	2	1	3	–	3	–	–	–	–	–	–	2	3

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

Understand the integration of Artificial Intelligence, Machine Learning, and computational engineering tools within MATLAB for intelligent engineering problem-solving and decision support.

Example Activity:

Develop a machine learning model for predicting the performance of a mechanical component.

- Import engineering performance data.
- Preprocess and analyze datasets.
- Train machine learning models using MATLAB.

- Evaluate prediction accuracy.
- Compare AI predictions with engineering calculations and experimental observations.

Students shall:

- Critically evaluate AI-generated engineering predictions.
- Compare machine learning results with conventional engineering methods.
- Validate computational models using engineering principles.
- Analyze limitations of AI-assisted engineering solutions.
- Reflect on ethical and professional responsibilities in intelligent engineering systems.

Assessment Scheme

Skill Enhancement Course (Practical)

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Experiments 1–5	CO1 / CO2 (L1–L2)	20	Fundamental understanding. Quiz / Demonstration / Assignment / Concept Test / Viva
CAT–2 – Apply	Experiments 6–10	CO2 / CO3 (L2–L3)	20	Application of skills. Hands-on Task / Practical Exercise / Problem Solving / Software Activity / Lab Task
CAT–3 – Analyze / Create	Experiments 11–15	CO3 / CO4 / CO5 (L3–L6)	20	Analysis, creation and application. Mini Project / Case Study / Design Task / Practical Demonstration / Presentation
Continuous Skill Assessment	Entire Course	As applicable	20	Practical Performance / Technical Assignment / Activity
Final Skill Demonstration	Entire Course	As applicable	20	Practical Demonstration / Viva / Project Presentation
Total CIA			**100**	**No SEE**

Suggested Reading

Reference Books

- Steven C. Chapra, Applied Numerical Methods with MATLAB for Engineers and Scientists, McGraw Hill.
- Amos Gilat, MATLAB: An Introduction with Applications, Wiley.
- Brian Hahn and Daniel T. Valentine, Essential MATLAB for Engineers and Scientists, Elsevier.
- Delores M. Etter, Engineering Problem Solving with MATLAB, Pearson.

Additional Resources

- MATLAB Online Documentation
- MATLAB Academy
- MathWorks Learning Center
- MATLAB Onramp Training
- Simulink Onramp Training

DLI Course Mapped

Fundamentals of Data Science https://learn.nvidia.com/

DLI Learning Path

- Data Science Fundamentals
- Machine Learning for Engineering Applications
- Deep Learning Fundamentals
- Engineering Analytics and Prediction

AI and Deep Learning for Design Engineers

(As per Choice Based Credit System)	
Course Code: 26MDE5217	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mathematics, Basic Programming Knowledge, Fundamentals of Design Engineering	
Course Type: Skill Enhancement Course (SEC)	**Hours/Week:** 04 **Total Hours:** 60 Hrs – 60 Hrs (Practical) **Credits:** 02
L – T – P – J: 0 – 0 – 4 – 0	

Course Vision

This course aims to equip design engineers with practical skills in Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Computer Vision, and Generative AI using NVIDIA Deep Learning Institute (DLI) resources. The course emphasizes the application of AI technologies in engineering design, product development, manufacturing, quality control, predictive analytics, and intelligent engineering systems.

Course Objectives

Students will be able to:

- Understand the fundamentals of Artificial Intelligence, Machine Learning, and Deep Learning.
- Develop AI and Deep Learning models using NVIDIA accelerated computing platforms.
- Apply Computer Vision techniques for engineering inspection and automation.
- Utilize Generative AI and Large Language Models (LLMs) for engineering applications.
- Develop AI-driven solutions for design optimization, predictive engineering, and smart manufacturing.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Apply AI and Machine Learning concepts to engineering design problems.	L3

CO	Course Outcome	BTL
CO2	Develop Deep Learning models using NVIDIA AI frameworks.	L3
CO3	Implement Computer Vision solutions for engineering and manufacturing applications.	L4
CO4	Utilize Generative AI tools for engineering design support and innovation.	L4
CO5	Develop AI-enabled engineering systems for intelligent product development and manufacturing.	L5

Broad Course Description

This Skill Enhancement Course introduces Artificial Intelligence and Deep Learning technologies specifically tailored for Design Engineers. The course combines theoretical understanding with extensive practical implementation using NVIDIA GPU-accelerated platforms and NVIDIA DLI learning resources.

Students will gain hands-on experience in machine learning, neural networks, deep learning architectures, computer vision, generative AI, engineering analytics, predictive maintenance, intelligent manufacturing, and AI-assisted design optimization.

The course is designed around laboratory exercises, industrial case studies, engineering datasets, AI-based mini-projects, and real-world applications relevant to Industry 4.0 and intelligent engineering systems.

Detailed Laboratory / Practical Syllabus

Laboratory Experiments and Practical Activities

This Skill Enhancement Course is conducted entirely in the laboratory (L – T – P – J: 0 – 0 – 4 – 0) and has no theory lectures. The 60 practical hours are organised as fifteen four-hour laboratory sessions on machine learning, deep learning, computer vision and generative AI for engineering design and manufacturing. Each session begins with a short demonstration and is followed by individual or small-group hands-on work; the procedure, results and inferences of every experiment are recorded in a laboratory record / digital portfolio.

Experiments 1–5 (initial skills), 6–10 (intermediate skills) and 11–15 (advanced skills and mini project) correspond to CAT–1, CAT–2 and CAT–3 of the Assessment Scheme respectively.

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
1	**Python and GPU Environment Setup with Exploratory Data Analysis**	Configure the Python, Jupyter and GPU environment; explore and visualise a mechanical engineering dataset.	CO1	4
2	**Machine Learning Regression for Design Performance Prediction**	Train and evaluate regression models to predict material properties or design performance; apply feature selection and cross-validation.	CO1	4
3	**Classification and Clustering of Engineering Data**	Apply classification and clustering to failure-mode or material-grouping data; compare performance metrics.	CO1	4
4	**Neural Network Implementation using PyTorch**	Build a feed-forward neural network for engineering regression; study activation and loss functions.	CO2	4
5	**Deep Learning Training on GPU and Hyperparameter Tuning**	Train models on GPU using NVIDIA DLI/NGC resources; tune learning rate, batch size and architecture and compare with CPU training.	CO2	4
6	**Deep Learning for Sensor Time-Series Prediction**	Use LSTM or 1D-CNN models on vibration/temperature sensor data to predict machine condition or remaining useful life.	CO2	4
7	**Image Dataset Preparation and Augmentation**	Collect, label and augment images of machined and welded components; prepare training and test sets.	CO3	4
8	**CNN Image Classification of Surface Defects**	Train a convolutional neural network to classify surface defects and evaluate it using a confusion matrix.	CO3	4
9	**Object Detection for Quality Inspection**	Apply an object-detection model (e.g., YOLO) to localise defects on manufactured parts.	CO3	4
10	**Transfer Learning and Inspection Model Evaluation**	Fine-tune a pretrained network for an inspection task, compare it with training from scratch and analyse errors.	CO3	4
11	**Prompt Engineering for Engineering Tasks**	Design and refine prompts for requirement analysis, FMEA drafting and code generation; critically verify the outputs.	CO4	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
12	**Generative Design and Concept Exploration**	Run a generative design study in Fusion 360 and use generative AI tools for concept ideation; compare the alternatives generated.	CO4	4
13	**LLM-Assisted Engineering Workflow**	Build a retrieval-based assistant over standards and datasheets for engineering queries; evaluate its accuracy and limitations.	CO4	4
14	**AI-Based Design Optimization and Predictive Analytics**	Combine a trained surrogate model with an optimizer for design optimization; perform predictive-maintenance analytics.	CO5	4
15	**AI-Based Engineering Capstone Project**	Develop and demonstrate an AI-enabled solution to a design or manufacturing problem; submit the code, dataset description, results and report.	CO5	4
Total Practical Hours				**60**

Laboratory Resources: Software, Tools and Equipment

- NVIDIA DLI Platform
- Python with JupyterLab
- PyTorch / TensorFlow and scikit-learn
- OpenCV for image processing
- GPU workstation or cloud GPU with NVIDIA NGC containers
- Large language model (LLM) and generative AI tools
- Autodesk Fusion 360 Generative Design

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	1	3	–	3	–	–	–	–	–	–	1	3
CO2	2	–	3	–	3	–	–	–	–	–	–	–	–
CO3	2	–	3	–	1	–	–	–	–	–	–	2	2
CO4	2	–	2	–	3	–	–	–	–	–	–	2	–
CO5	2	–	3	–	2	–	–	–	–	–	–	3	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

Develop intelligent engineering solutions by integrating Artificial Intelligence, Deep Learning, Computer Vision, and Generative AI into modern design engineering workflows.

Example Activity:

Develop an AI-assisted design optimization system for a mechanical component.

- Collect engineering design and performance data.
- Train machine learning and deep learning models.
- Generate design alternatives using Generative AI tools.
- Evaluate performance predictions.
- Recommend optimized engineering solutions.

Students shall:

- Critically evaluate AI-generated engineering recommendations.
- Validate AI predictions using engineering principles.
- Compare conventional and AI-driven design methodologies.
- Analyze limitations, risks, and uncertainties of AI systems.
- Reflect on ethical, professional, and societal implications of AI adoption in engineering practice.

Assessment Scheme

Skill Enhancement Course (Practical)

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Experiments 1–5	CO1 / CO2 (L1–L2)	20	Fundamental understanding. Quiz / Demonstration / Assignment / Concept Test / Viva
CAT–2 – Apply	Experiments 6–10	CO2 / CO3 (L2–L3)	20	Application of skills. Hands-on Task / Practical Exercise / Problem Solving / Software Activity / Lab Task
CAT–3 – Analyze / Create	Experiments 11–15	CO3 / CO4 / CO5 (L3–L6)	20	Analysis, creation and application. Mini Project / Case Study / Design Task / Practical Demonstration / Presentation
Continuous Skill Assessment	Entire Course	As applicable	20	Practical Performance / Technical Assignment / Activity
Final Skill Demonstration	Entire Course	As applicable	20	Practical Demonstration / Viva / Project Presentation
Total CIA			**100**	**No SEE**

Suggested Reading

Reference Books

- Steven L. Brunton and J. Nathan Kutz, Data-Driven Science and Engineering, Cambridge University Press.
- Kevin P. Murphy, Machine Learning: A Probabilistic Perspective, MIT Press.
- Christopher M. Bishop, Pattern Recognition and Machine Learning, Springer.
- Richard S. Sutton and Andrew G. Barto, Reinforcement Learning: An Introduction, MIT Press.

Additional Resources

- NVIDIA Deep Learning Institute (DLI)
- NVIDIA Developer Portal
- TensorFlow Documentation
- PyTorch Documentation
- OpenCV Documentation

DLI Course Mapped

Fundamentals of Deep Learning https://learn.nvidia.com/

DLI Learning Path

- Fundamentals of Deep Learning
- Building Transformer-Based NLP Applications
- Generative AI Explained
- Applications of AI for Predictive Maintenance

Engineering Makerspace and Product Prototyping

(As per Choice Based Credit System)

Course Code: 26MDE5218	**Semester:** II
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Graphics, Product Design Fundamentals, Manufacturing Processes	
Course Type: Skill Enhancement Course (SEC)	**Hours/Week:** 04 **Total Hours:** 60 Hrs – 60 Hrs (Practical) **Credits:** 02
L – T – P – J: 0 – 0 – 4 – 0	

Course Vision

This course aims to foster innovation, creativity, and hands-on product realization skills by providing experiential learning in engineering makerspaces. The course emphasizes design thinking, rapid prototyping, digital fabrication, electronics integration, product validation, and entrepreneurship-oriented product development for modern engineering applications.

Course Objectives

Students will be able to:

- Apply design thinking methodologies for product innovation and development.
- Utilize makerspace tools and rapid prototyping technologies for product realization.
- Develop functional prototypes using digital fabrication techniques.
- Integrate mechanical, electronic, and IoT components into engineering products.
- Design, fabricate, test, and validate innovative engineering solutions.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Apply design thinking principles to identify and solve engineering problems.	L3
CO2	Develop engineering concepts using digital design and prototyping	L3

CO	Course Outcome	BTL
	tools.	
CO3	Fabricate and evaluate engineering prototypes using makerspace technologies.	L4
CO4	Integrate sensors, electronics, and embedded systems into product prototypes.	L4
CO5	Develop innovative functional products and demonstrate entrepreneurial engineering capabilities.	L5

Broad Course Description

This Skill Enhancement Course focuses on experiential learning through engineering makerspaces and product prototyping environments. The course provides hands-on exposure to design thinking, innovation methodologies, rapid prototyping, additive manufacturing, laser cutting, embedded systems, IoT integration, product testing, and validation.

Students will work on multidisciplinary engineering projects involving conceptualization, design, prototyping, testing, refinement, and product demonstration. The course promotes creativity, collaborative problem-solving, entrepreneurship, and innovation-driven engineering practices.

The course is delivered through makerspace activities, design challenges, fabrication exercises, industrial case studies, prototype development projects, and innovation showcases.

Detailed Laboratory / Practical Syllabus

Laboratory Experiments and Practical Activities

This Skill Enhancement Course is conducted entirely in the laboratory (L – T – P – J: 0 – 0 – 4 – 0) and has no theory lectures. The 60 practical hours are organised as fifteen four-hour laboratory sessions on design thinking, digital fabrication, embedded electronics and product prototyping in the makerspace. Each session begins with a short demonstration and is followed by individual or small-group hands-on work; the procedure, results and inferences of every experiment are recorded in a laboratory record / digital portfolio.

Experiments 1–5 (initial skills), 6–10 (intermediate skills) and 11–15 (advanced skills and mini project) correspond to CAT–1, CAT–2 and CAT–3 of the Assessment Scheme respectively.

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
1	**Makerspace Orientation, Safety and Design Thinking Workshop**	Complete safety induction and machine familiarisation; empathise with users and define a real-world problem using interviews and empathy maps.	CO1	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
2	**Ideation and Concept Generation**	Apply brainstorming, SCAMPER and sketching to generate and document multiple concepts for the selected problem.	CO1	4
3	**Concept Selection and Low-Fidelity Prototyping**	Evaluate concepts using a decision matrix; build a low-fidelity (cardboard/foam) prototype and collect user feedback.	CO1	4
4	**CAD Modelling of the Selected Concept**	Create parametric 3D models of the product's parts in Fusion 360.	CO2	4
5	**Design for Prototyping and Assembly**	Apply DFM/DFAM principles, fits and tolerances; prepare the assembly, exploded view and drawings.	CO2	4
6	**Digital Validation and Fabrication File Preparation**	Carry out a basic simulation or topology study; export STL/DXF files for fabrication.	CO2	4
7	**3D Printing of Prototype Components**	Slice, print and post-process FDM parts; study the effect of print parameters on quality.	CO3	4
8	**Laser Cutting and Engraving**	Design 2D profiles and fabricate parts by laser cutting; assemble press-fit and slotted joints.	CO3	4
9	**Digital Fabrication, Assembly and Finishing**	Use hand and power tools (and CNC router/vinyl cutter where available) to finish and assemble the prototype.	CO3	4
10	**Prototype Evaluation and Design Iteration**	Inspect dimensions, fits and function; record and implement design improvements.	CO3	4
11	**Electronics Fundamentals with Arduino**	Build breadboard circuits with LEDs, switches and sensors (temperature, ultrasonic) on Arduino; measure signals with a multimeter.	CO4	4
12	**Microcontroller Control of Actuators**	Control a servo, DC motor or relay from sensor inputs and integrate the electronics into the prototype.	CO4	4
13	**IoT-Enabled Smart Prototype**	Connect an ESP32/Arduino to Wi-Fi; log and display sensor data on a cloud dashboard.	CO4	4
14	**Product Testing, Validation and Documentation**	Conduct functional and performance tests; prepare the BOM, cost estimate, documentation and user manual.	CO5	4

Exp. No.	Laboratory Experiment / Practical Activity	Hands-on Tasks, Tools and Expected Output	CO	Hours
15	**Makerspace Capstone Project and Innovation Pitch**	Deliver a functional product prototype, demonstrate it and present an innovation pitch with a business model canvas.	CO5	4
Total Practical Hours				**60**

Laboratory Resources: Software, Tools and Equipment

- Autodesk Fusion 360
- Slicer software (Cura / PrusaSlicer) and FDM 3D printers
- Laser cutter/engraver and hand and power tools
- Arduino IDE, Arduino and ESP32 boards
- Sensors, actuators and breadboard/electronics kits
- IoT dashboard platform (e.g., Blynk / ThingSpeak)
- Measuring instruments (vernier calipers, multimeter)

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	2	–	1	–	–	–	–	–	–	1	–
CO2	2	–	3	–	3	–	–	–	–	–	–	1	–
CO3	2	2	–	–	1	–	–	–	–	–	–	3	–
CO4	2	–	–	–	1	–	–	–	–	–	–	3	–
CO5	2	–	3	–	1	–	–	–	–	–	–	2	–

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

Understand the role of Artificial Intelligence in product innovation, generative design, rapid prototyping, smart product development, and intelligent manufacturing.

Example Activity:

Develop an AI-assisted innovative product concept using generative design and intelligent prototyping tools.

- Identify a real-world engineering problem.
- Generate multiple design alternatives using AI-assisted tools.
- Evaluate functional and manufacturing constraints.
- Fabricate the selected prototype.
- Analyze performance and innovation potential.

Students shall:

- Critically evaluate AI-generated design alternatives.
- Compare AI-assisted and human-generated product concepts.
- Validate product functionality through physical prototyping.
- Analyze innovation feasibility and user acceptance.
- Reflect on ethical, environmental, and societal implications of engineering innovations.

Assessment Scheme

Skill Enhancement Course (Practical)

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Experiments 1–5	CO1 / CO2 (L1–L2)	20	Fundamental understanding. Quiz / Demonstration / Assignment / Concept Test / Viva
CAT–2 – Apply	Experiments 6–10	CO2 / CO3 (L2–L3)	20	Application of skills. Hands-on Task / Practical Exercise / Problem Solving / Software Activity / Lab Task
CAT–3 – Analyze / Create	Experiments 11–15	CO3 / CO4 / CO5 (L3–L6)	20	Analysis, creation and application. Mini Project / Case Study / Design Task / Practical Demonstration / Presentation
Continuous Skill Assessment	Entire Course	As applicable	20	Practical Performance / Technical Assignment / Activity
Final Skill Demonstration	Entire Course	As applicable	20	Practical Demonstration / Viva / Project Presentation
Total CIA			**100**	**No SEE**

Suggested Reading

Reference Books

- Karl T. Ulrich and Steven D. Eppinger, Product Design and Development, McGraw Hill.
- John R. Karsnitz, Stephen O'Brien, and John P. Hutchinson, Engineering Design: An Introduction, Cengage Learning.
- Chua Chee Kai and Kah Fai Leong, 3D Printing and Additive Manufacturing: Principles and Applications, World Scientific.
- Simon Monk, Programming Arduino: Getting Started with Sketches, McGraw Hill.

Additional Resources

- Autodesk Design Academy
- MIT Design Thinking Resources
- Arduino Learning Portal
- Makerspace Design Guides
- NPTEL – Product Design and Development

DLI Course Mapped

Building Digital Twins for Physical AI With NVIDIA Omniverse
https://learn.nvidia.com/

DLI Learning Path

- AI-Assisted Product Design
- Generative Design and Optimization
- Smart Product Development
- IoT and Embedded Intelligence

Dissertation– Phase I

(As per Choice Based Credit System)

Course Code: 26MDE5301	**Semester:** III
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Research Methodology, Advanced Solid Mechanics, Domain Elective Courses of Semesters I & II	
Course Type: Research Project	**Hours/Week:** 12 **Total Hours:** 180 Hrs (Project / Research Work) **Credits:** 06
L – T – P – J: 0 – 0 – 0 – 12	

Purpose and Scope

Dissertation / Research Project Phase I provides postgraduate students the opportunity to identify a research or design problem in the field of Mechanical / Design Engineering, carry out a systematic literature review, and formulate a well-defined problem statement, objectives, and methodology under the guidance of a faculty supervisor. The activity forms the foundation for the full dissertation work to be completed in Semester IV.

Course/Activity Objectives

Students will be able to:

- Identify a relevant research or design problem aligned with the student's area of specialization.
- Conduct a systematic literature review and critically analyse existing work in the chosen area.
- Formulate clear research objectives, scope, and a feasible methodology / work plan.
- Apply appropriate analytical, computational, or experimental techniques to generate preliminary results.
- Document and present the problem formulation and preliminary findings in a structured technical report.

Learning Outcomes

- Formulate a research/design problem with clearly defined objectives and scope.
- Critically review and synthesize literature relevant to the chosen problem area.
- Develop a sound methodology / work plan for carrying out the proposed research or design work.
- Demonstrate preliminary analytical, computational, or experimental competence in the chosen domain.
- Communicate research progress effectively through written reports and oral presentation.

Methodology / Work Plan

The student, in consultation with the allotted supervisor, shall select a topic of research or design

relevant to Mechanical / Design Engineering. The work shall proceed through problem identification, literature survey, objective formulation, methodology selection, and preliminary investigation (analytical, computational, or experimental as applicable). Periodic guidance meetings with the supervisor shall be held to monitor progress and refine the direction of work.

Project / Research Milestones

- Milestone 1: Topic selection and preliminary literature survey (Weeks 1–3).
- Milestone 2: Detailed literature review and problem formulation (Weeks 4–7).
- Milestone 3: Finalization of objectives, scope, and methodology (Weeks 8–10).
- Milestone 4: Preliminary analysis / modelling / experimentation (Weeks 11–13).
- Milestone 5: Compilation of Phase I report and presentation (Weeks 14–15).

Review and Progress Evaluation

Progress shall be monitored through periodic review meetings with the supervisor and a Departmental Review Committee. A minimum of two formal progress reviews shall be conducted during the semester, assessing the clarity of problem definition, depth of literature review, soundness of methodology, and quality of preliminary work.

Expected Deliverables / Outcomes

- A comprehensive literature review report.
- A clearly defined problem statement, objectives, and scope of work.
- A detailed methodology / work plan for Phase II.
- Preliminary results, models, or experimental data (as applicable).
- A Phase I dissertation report.

Report / Documentation Requirements

The student shall submit a Phase I Dissertation Report prepared in the format prescribed by the Department, comprising the introduction, literature review, problem formulation, objectives, methodology, preliminary results (if any), and a work plan for Phase II. The report shall follow standard academic writing conventions with proper citation of all referenced literature.

Presentation and Viva-Voce

The student shall deliver a formal presentation of the Phase I work before the Departmental Review Committee, followed by a viva-voce examination to assess the student's understanding of the problem, methodology, and preliminary outcomes.

Duration and Workload

Dissertation / Research Project Phase I is carried out over Semester III with an equivalent workload of 12 hours per week (180 hours total), corresponding to 06 credits, under continuous guidance from the allotted supervisor.

Assessment Scheme

– Assessment for Project Phase–I is based entirely on Continuous Internal Assessment (CIA), carrying a weightage of 100%, assessed jointly by the supervisor and the Departmental Review

Committee. There is no Semester End Examination (SEE) / External Examination for this phase, as detailed in the table below.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
Project Review–I – Problem Identification	Problem definition, background and motivation	Relevant COs (L2–L3)	20	Problem identification, literature survey, problem statement and objectives
Project Review–II – Literature Review & Gap Analysis	Literature review and research gap	Relevant COs (L2–L4)	20	Literature review, gap identification, critical analysis and formulation of objectives
Project Review–III – Methodology & Planning	Proposed methodology, design and work plan	Relevant COs (L3–L4)	20	Methodology presentation, design approach, simulation/experimental planning and project schedule
Project Progress / Preliminary Work	Initial implementation, modelling, simulation or experimentation	Relevant COs (L3–L5)	20	Preliminary results, technical progress, analysis and discussion
Project Report & Presentation	Phase–I report and presentation	Relevant COs (L4–L6)	10	Technical documentation, presentation and response to questions
Supervisor Assessment	Continuous project work	Relevant COs	10	Regularity, initiative, technical contribution, attendance and progress
Total Internal Assessment	**Dissertation–Phase I**		**100**	**Internal Assessment only – No SEE / External Examination**

Internship

(As per Choice Based Credit System)

Course Code: 26MDE5302	**Semester:** III
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Domain Elective Courses of Semesters I & II, Basic Professional and Communication Skills	
Course Type: Internship	**Hours/Week:** 12 **Total Hours:** 180 Hrs (Industrial / Research Internship) **Credits:** 06
L – T – P – J: 0 – 0 – 0 – 12	

Purpose and Scope

The Internship provides postgraduate students with structured exposure to industrial, research, or R&D environments relevant to Mechanical / Design Engineering. It enables students to apply classroom knowledge to real-world engineering problems, understand industrial practices and workflows, and develop professional and technical competencies under the mentorship of an industry/research supervisor and a faculty coordinator.

Course/Activity Objectives

Students will be able to:

- Gain exposure to real-world engineering design, manufacturing, or research practices in an industrial or R&D setting.
- Apply theoretical knowledge of design engineering to practical problems assigned by the host organization.
- Understand industrial workflows, tools, standards, and quality/safety practices.
- Develop professional skills including teamwork, communication, and technical documentation.
- Critically reflect on the relationship between academic learning and industrial practice.

Learning Outcomes

- Demonstrate the ability to work effectively within an industrial or research organization.
- Apply design engineering concepts and tools to solve assigned practical problems.
- Describe and critically evaluate industrial processes, tools, and standards relevant to the host organization.
- Prepare professional technical documentation and reports summarizing internship activities and outcomes.
- Communicate internship outcomes effectively through written reports and oral presentation.

Internship Activities and Responsibilities

The student shall be attached to an industry, R&D organization, or research laboratory approved by

the Department for a minimum duration equivalent to 12 hours per week (180 hours) during Semester III. Activities may include design and analysis tasks, manufacturing or process support, testing and validation, software/tool usage, or research assistance, as assigned by the host organization, under the joint supervision of an industry mentor and a faculty coordinator.

Project / Research Milestones

- Milestone 1: Induction, orientation, and understanding of organizational workflow (Weeks 1–2).
- Milestone 2: Assignment of tasks/project and initial contribution (Weeks 3–6).
- Milestone 3: Substantive technical contribution to assigned tasks (Weeks 7–11).
- Milestone 4: Consolidation of outcomes and documentation (Weeks 12–14).
- Milestone 5: Submission of internship report and presentation (Week 15).

Review and Progress Evaluation

Progress shall be jointly monitored by the industry mentor and the faculty coordinator through periodic progress reports and at least one mid-term review. The industry mentor shall provide a certificate/feedback on the student's performance, attendance, and conduct at the end of the internship.

Expected Deliverables / Outcomes

- A certificate of completion / performance feedback from the host organization.
- A detailed internship report describing the organization, tasks performed, and outcomes achieved.
- Technical documentation, drawings, code, or data generated during the internship, as applicable.
- A reflective account of learning outcomes and their relevance to the student's academic and career goals.

Report / Documentation Requirements

The student shall submit an Internship Report in the format prescribed by the Department, covering an overview of the host organization, description of assigned tasks and methodology, technical contributions, outcomes achieved, and a reflection on learning gained. The report shall be duly certified by the industry mentor and faculty coordinator.

Presentation and Viva-Voce

On completion of the internship, the student shall present a summary of the internship experience and outcomes before the Departmental Review Committee, followed by a viva-voce examination.

Duration and Workload

The Internship is carried out over Semester III with an equivalent workload of 12 hours per week (180 hours total), corresponding to 06 credits, under the joint supervision of an industry mentor and a faculty coordinator.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA). The weightage of this component is 100%, assessed jointly by the supervisor/mentor and the Departmental Review Committee based on the components below.

Assessment Component	Marks (CIE = 60)
Industry Mentor Feedback / Overall Internship Performance	20
Faculty Coordinator / Supervisor Review	15
Technical Learning & Skill Development	15
Application of Engineering Knowledge / Problem-Solving	15
Internship Report	15
Presentation	10
Viva-Voce / Technical Defence	10
Total	**100 marks**

Advanced Automotive Control and Mobility Systems

(As per Choice Based Credit System)	
Course Code: 26MDE5303	**Semester:** III
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Control Systems, Automotive Engineering Fundamentals, Mechatronic System Design	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop advanced competency in automotive control systems and intelligent mobility technologies, covering vehicle dynamics, electronic control units, sensors and actuators, and electric and autonomous vehicle concepts. The course enables postgraduate learners to analyse, design, and evaluate modern automotive control and mobility systems using simulation and diagnostic techniques.

Course Objectives

Students will be able to:

- Gain knowledge of basic automotive systems and vehicle control principles.
- Understand sensors, actuators, and electronic control units used in modern vehicles.
- Develop skills to analyse mobility systems and intelligent transportation technologies.
- Understand electric and autonomous vehicle concepts and their applications.
- Make use of simulation and diagnostic techniques for automotive control and mobility systems.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the fundamental concepts of automotive systems, vehicle architecture, and vehicle control.	L2

CO	Course Outcome	BTL
CO2	Analyze sensors, actuators, electronic control units, and communication protocols used in vehicle control applications.	L4
CO3	Apply intelligent mobility concepts and transportation technologies in modern automotive systems.	L3
CO4	Apply electric and autonomous vehicle concepts to mobility applications.	L3
CO5	Analyze automotive diagnostics, safety systems, and simulation techniques for reliable vehicle operation.	L4

Broad Course Description

This course introduces advanced automotive control and mobility systems with emphasis on practical engineering applications. It covers vehicle dynamics, sensors and actuators, electronic control units, communication systems, intelligent transportation systems, electric mobility, and autonomous vehicle technologies. Students gain exposure to modern automotive technologies through laboratory exercises, simulations, and real-world case studies. The course also introduces sustainable transportation concepts and smart mobility solutions for future transportation systems.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Automotive Systems and Vehicle Control (9 Hours)

Introduction to automotive systems, vehicle architecture, fundamentals of vehicle dynamics, braking systems, steering systems, suspension systems, engine basics, transmission systems, introduction to vehicle control systems, fundamentals of automotive electronics.

Engineering Applications: Basic vehicle speed control system, braking efficiency analysis, steering response monitoring system.

Module 2: Sensors, Actuators and Electronic Control Units (9 Hours)

Types of automotive sensors, temperature sensors, speed sensors, pressure sensors, proximity sensors, actuators, control valves, motors, introduction to Electronic Control Units (ECU), Controller Area Network (CAN), vehicle communication systems, diagnostics and fault detection.

Engineering Applications: Engine temperature monitoring system, automated lighting control system, tire pressure monitoring system.

Module 3: Intelligent Mobility and Transportation Systems (9 Hours)

Introduction to intelligent transportation systems, traffic management systems, vehicle-to-vehicle communication, vehicle-to-infrastructure communication, smart mobility concepts, connected

vehicles, navigation systems, mobility data analysis, introduction to sustainable transportation systems.

Engineering Applications: Smart traffic signal system, intelligent parking management system, connected vehicle monitoring system.

Module 4: Electric and Autonomous Vehicles (9 Hours)

Introduction to electric vehicles, battery systems, charging systems, hybrid vehicles, regenerative braking, fundamentals of autonomous vehicles, driver assistance systems, lane detection concepts, adaptive cruise control, safety considerations in autonomous mobility.

Engineering Applications: Battery monitoring system, electric vehicle charging management system, adaptive cruise control simulation.

Module 5: Automotive Safety, Diagnostics and Simulation (9 Hours)

Automotive safety systems, anti-lock braking systems, airbags, stability control systems, automotive diagnostics, fault identification, simulation techniques, introduction to automotive simulation software, reliability and maintenance concepts, future trends in mobility systems.

Engineering Applications: Vehicle fault diagnostic system, safety alert system, simulation-based vehicle performance analysis.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	2	–	1	–	–	–	–	–	–	–	–
CO2	2	3	2	–	1	–	–	–	–	2	–	–	3
CO3	2	–	–	–	1	–	–	–	–	–	–	–	–
CO4	2	–	3	–	1	–	–	–	–	–	–	–	–
CO5	2	3	–	–	3	2	–	–	–	–	–	–	–

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

- Collect vehicle speed input
- Monitor braking conditions
- Analyze steering conditions
- Display control status information

Module 2: Implement a sensor-based monitoring system:

- Read sensor values
- Detect abnormal conditions
- Process actuator responses
- Generate fault alerts

Module 3: Implement a smart mobility analysis system:

- Collect traffic data
- Analyze congestion levels
- Display traffic patterns
- Suggest optimized mobility solutions

Module 4: Implement a basic electric vehicle model:

- Monitor battery levels
- Analyze charging conditions
- Simulate energy usage
- Display vehicle performance parameters

Module 5: Develop a vehicle diagnostic system:

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Embedded Platforms: Arduino, Raspberry Pi
- Mobility Analysis Tools: Python, Data Visualization Tools
- AI-Assisted Development Tools: ChatGPT, GitHub Copilot, automotive diagnostic tools

Suggested Reading

Reference Books

- Konrad Reif, "Automotive Mechatronics: Automotive Networking, Driving Stability Systems, Electronics", Springer Vieweg, 2nd Edition, 2015.
- Iqbal Husain, "Electric and Hybrid Vehicles: Design Fundamentals", CRC Press, 3rd Edition, 2021.
- Ljubo Vlacic, Michel Parent, and Fumio Harashima, "Intelligent Vehicle Technologies", Elsevier, 1st Edition, 2001.
- Tom Denton, "Automobile Mechanical and Electrical Systems", Routledge, 5th Edition, 2017.
- Mehrdad Ehsani, Yimin Gao, and Ali Emadi, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals, Theory, and Design", CRC Press, 3rd Edition, 2018.

Additional Resources

- NPTEL – Introduction to Automotive Engineering.
- SAE International Learning Resources and Mobility Standards. Coursera – Electric Vehicles and Mobility Courses.
- edX – Autonomous Vehicle and Smart Mobility Programs. MATLAB and Simulink Automotive Simulation Resources.

DLI Course Mapped

Fundamentals of Autonomous Vehicles and Smart Mobility Systems
https://learn.nvidia.com/

DLI Learning Path

- Autonomous Vehicles and Smart Mobility Computing

- AI for Intelligent Transportation Systems
- Edge AI for Automotive Control

Robotics Simulation and Digital Prototyping

(As per Choice Based Credit System)	
Course Code: 26MDE5304	**Semester:** III
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Robotics Fundamentals, CAD/CAM, Basics of Automation and Control Systems	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop advanced competency in robotics simulation, digital prototyping, and virtual validation techniques for modern industrial automation systems. The course enables learners to design, simulate, analyze, and optimize robotic systems in virtual environments prior to physical implementation.

Course Objectives

Students will be able to:

- Understand the fundamentals of robotics simulation and digital prototyping methodologies.
- Explore virtual robotic workcell design and simulation environments.
- Apply digital prototyping techniques for robotic motion planning and system validation.
- Analyze robot kinematics, trajectory planning, and collision detection using simulation tools.
- Develop intelligent robotic simulation models for industrial automation applications.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain robotic modeling, kinematics, and simulation principles used in industrial automation.	L2
CO2	Analyze robotic motion, path planning, collision detection, and workcell layouts in virtual environments.	L4
CO3	Develop digital prototypes and apply virtual commissioning techniques for robotic automation systems and manufacturing	L3

CO	Course Outcome	BTL
	applications.	
CO4	Apply digital twin, AI-integrated, and autonomous-system simulation techniques to model and optimize robotic system performance.	L3
CO5	Analyze emerging trends in robotics simulation, including cloud robotics and AR/VR-based simulation, for future intelligent automation.	L4

Broad Course Description

This course introduces advanced concepts of robotics simulation and digital prototyping used in modern smart manufacturing and industrial automation environments. The course focuses on the creation of virtual robotic systems for design validation, motion analysis, process optimization, and performance evaluation before physical deployment.

Learners will gain exposure to:

- Robotics simulation environments
- Digital prototyping methodologies
- Robot kinematics and motion simulation
- Virtual workcell design and automation

Detailed Course Syllabus

Course Modules

Module 1: Robotic Modeling and Kinematics Simulation (9 Hours)

Robot classifications and configurations. Coordinate systems and transformations. Forward and inverse kinematics. Denavit-Hartenberg (D-H) parameters. Workspace analysis. Robot motion simulation. End-effector positioning and orientation. Simulation of articulated and SCARA robots.

Engineering Applications: *Pick-and-place robots, robotic manipulators, packaging automation systems.*

Module 2: Motion Planning and Workcell Simulation (9 Hours)

Trajectory generation techniques. Joint space and Cartesian space motion planning. Path interpolation methods. Collision detection and avoidance algorithms. Robotic workcell modeling. Sensor integration in robotic simulations. Cycle time analysis and optimization. Human-robot interaction in virtual environments.

Engineering Applications: *CNC loading robots, robotic palletizing systems, collaborative robots (Cobots).*

Module 3: Digital Prototyping and Virtual Commissioning (9 Hours)

Concept of digital prototyping in manufacturing. Virtual validation of robotic systems. PLC and robot communication simulation. Offline robot programming. Simulation-based debugging and optimization. Virtual commissioning methodologies. Integration of CAD models into robotic simulations. Smart factory simulation concepts.

Engineering Applications: *Flexible manufacturing systems, robotic assembly stations, Industry 4.0 production lines.*

Module 4: Advanced Robotics Simulation (9 Hours)

Digital twins in robotics and manufacturing. AI integration in robotic simulations. Autonomous robotic systems. Simulation for additive manufacturing robots.

Engineering Applications: *Autonomous mobile robots, warehouse automation, smart logistics systems*

Module 5: Emerging Trends (9 Hours)

Cloud robotics and remote monitoring. Augmented reality (AR) and virtual reality (VR) in robotic simulation. Future trends in intelligent robotic automation.

Engineering Applications: *Cloud-connected robot fleet monitoring, AR/VR-based robot programming and operator training, remote inspection and maintenance robots.*

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	–	–	–	3	–	–	–	–	–	–	–	2
CO2	2	3	–	–	1	–	3	–	–	–	–	–	3
CO3	2	–	3	–	2	–	–	–	–	–	–	3	3
CO4	2	3	2	–	1	–	–	–	–	–	–	–	3
CO5	2	3	2	–	1	–	–	–	–	–	–	–	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

Understand how AI-assisted robotics simulation can optimize robotic motion planning, collision avoidance, and intelligent automation workflows.

Example Activity:

Develop a virtual robotic workcell simulation for automated material handling:

- Create a robotic workcell layout.

- Define robot trajectories and operational sequences.
- Simulate collision-free robotic movements.
- Analyze cycle time and workspace efficiency.
- Optimize robotic operations using AI-assisted path planning techniques.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- ABB RobotStudio

- FANUC ROBOGUIDE
- Siemens Process Simulate
- RoboDK
- MATLAB Robotics Toolbox
- Visual Components

Suggested Reading

Reference Books

- John J. Craig, Introduction to Robotics: Mechanics and Control, Pearson.
- Mikell P. Groover, Automation, Production Systems and Computer-Integrated Manufacturing, Pearson.
- Saeed B. Niku, Introduction to Robotics: Analysis, Control, Applications, Wiley.
- Peter Corke, Robotics, Vision and Control, Springer.

Additional Resources

- NPTEL – Robotics and Industrial Automation
- ABB RobotStudio Tutorials
- FANUC Robotics Learning Modules
- Siemens Tecnomatix Learning Resources
- MATLAB Robotics Documentation

DLI Course Mapped

NVIDIA AI for Robotics https://learn.nvidia.com/

DLI Learning Path

- NVIDIA AI for Robotics
- Robotics Simulation using Digital Twins
- Smart Manufacturing and Industrial Automation

Engineering Optimization and Decision-Making Techniques

(As per Choice Based Credit System)	
Course Code: 26MDE5305	**Semester:** III
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mathematics, Linear Algebra	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course develops the analytical and computational skills needed to formulate, model, and solve complex engineering optimization and decision-making problems. Learners will gain proficiency in both single- and multi-objective optimization techniques — covering unconstrained and constrained methods, optimality conditions, and post-optimality sensitivity analysis — with direct applications in mechanical engineering design and manufacturing. The course nurtures structured thinking from problem identification through solution generation to informed decision-making, and culminates in a real-world multi-objective engineering project that integrates all course concepts.

Course Objectives

Students will be able to:

- Understand the fundamental concepts of single- and multi-objective optimization and their role in mechanical engineering design and manufacturing.
- Identify and formulate real-world engineering problems as structured optimization problems with objectives, constraints, and design variables.
- Apply unconstrained and constrained optimization methods to generate feasible and optimal solutions.
- Evaluate solution quality using optimality conditions and post-optimality sensitivity analysis to support informed decision-making.
- Implement and assess engineering solutions through structured decision frameworks and a semester-long multi-objective engineering project.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain unconstrained and constrained optimization methods, including gradient-based, Lagrange multiplier, KKT, and penalty methods, used to generate feasible engineering solutions.	L2
CO2	Analyze optimality conditions and perform post-optimality and sensitivity analysis for engineering optimization problems.	L4
CO3	Apply structured decision-making frameworks such as AHP and TOPSIS to evaluate and implement engineering solutions.	L3
CO4	Formulate a real-world multi-objective engineering problem and select appropriate optimization and decision-making methods for the project.	L3
CO5	Analyze candidate solutions and Pareto fronts of a multi-objective engineering project, select the final solution using structured decision frameworks, and report the outcomes.	L4

Broad Course Description

This course provides a rigorous and application-driven treatment of optimization and decision-making for mechanical engineering. Beginning with problem identification and formulation, students progress through classical and modern optimization methods, optimality conditions, and multi-objective decision strategies. A strong emphasis is placed on engineering applications across design, manufacturing, structural, thermal, and materials domains.

Core areas of study include: optimization problem formulation (objectives, constraints, design variables), unconstrained optimization (gradient descent, Newton's method, golden section search), constrained optimization (Lagrange multipliers, KKT conditions, penalty methods), multi-objective optimization (Pareto front, weighted sum, epsilon-constraint methods), and decision-making frameworks (AHP, TOPSIS, and sensitivity-driven approaches). Through a blend of theory and practical lab exercises, students develop the ability to translate engineering challenges into solvable computational models and validate solutions using modern tools.

Detailed Course Syllabus

Course Modules

Module 1: Generate Solutions (9 Hours)

Unconstrained optimization methods: Golden Section Search, gradient descent, steepest descent, Newton's method, conjugate gradient method. Constrained optimization methods: Lagrange multiplier method, KKT (Karush-Kuhn-Tucker) conditions, penalty function method, augmented

Lagrangian method. Linear programming fundamentals: graphical method, simplex method. Introduction to numerical optimization libraries and solvers.

Engineering Applications: *Heat exchanger surface optimization, cam profile generation, truss design under load constraints.*

Module 2: Make the Decision (9 Hours)

Optimality conditions and verification: first-order and second-order conditions, constraint qualification. Post-optimality sensitivity analysis: parametric sensitivity, shadow prices, active constraint analysis. Multi-objective optimization: concept of Pareto optimality, Pareto front generation. Multi-objective methods: weighted sum method, epsilon-constraint method, goal programming. Decision-making under multiple objectives: trade-off analysis and compromise solutions.

Engineering Applications: *Multi-criteria material selection, engine component trade-off analysis, manufacturing process parameter optimization.*

Module 3: Implement and Assess the Solution (9 Hours)

Structured decision frameworks: Analytic Hierarchy Process (AHP), TOPSIS, value function methods. Implementation of solutions: translating optimization output into engineering specifications. Solution validation and feasibility checks. Sensitivity-driven redesign: iterating solutions under changing constraints or objectives. Introduction to metaheuristic methods: Genetic Algorithms, Simulated Annealing, Particle Swarm Optimization — concepts and engineering applications. Profiling and benchmarking optimization runs.

Engineering Applications: *Supplier selection using AHP, robustness evaluation of designed components, real-time process control optimization.*

Module 4: Multi-Objective Engineering Project – Formulation and Methodology (9 Hours)

Semester-long real-world multi-objective engineering project integrating all course modules. Students select a mechanical engineering design or manufacturing problem, formulate it as a multi-objective optimization problem, and select appropriate methods from Modules 1–3, including project scoping, problem formulation, and literature review and benchmarking of existing approaches.

Engineering Applications: Sustainable product design (cost vs. environmental impact), CNC machining parameter optimization (surface finish vs. material removal rate), lightweight structural design (weight vs. stiffness vs. cost).

Module 5: Multi-Objective Engineering Project – Solution, Validation and Reporting (9 Hours)

Application of selected optimization and decision-making methods to generate candidate solutions and Pareto front visualization for the chosen engineering project. Decision-making and final solution selection using structured frameworks. Sensitivity analysis and decision rationale for the selected solution. Technical report writing and oral presentation of the complete project, including problem formulation, methodology, results, and conclusions.

Engineering Applications: Pareto-front trade-off reports for lightweight bracket design

(weight vs. stiffness vs. cost), AHP/TOPSIS-based selection of CNC machining parameters, sensitivity-based design review for sustainable product development.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	–	2	–	2	–	–	–	–	–	–	–	2
CO2	2	3	2	–	1	–	–	–	–	–	–	–	3
CO3	1	2	–	–	1	–	–	–	–	–	–	–	3
CO4	2	3	3	–	1	–	–	–	–	–	–	–	–
CO5	2	–	3	–	1	–	–	–	–	–	–	2	3

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Understand how Artificial Intelligence and machine learning enhance engineering optimization and decision-making processes under uncertainty and complexity.

Example Activities:

- Develop a machine-learning-based surrogate model to accelerate an engineering optimization problem.
- Apply AI-assisted multi-criteria decision-making techniques to an engineering design-selection problem.
- Evaluate reinforcement-learning approaches for sequential engineering decision-making.
- Simulate AI-assisted sensitivity and uncertainty analysis for an optimization problem.
- Compare classical optimization algorithms with AI/metaheuristic-based optimization techniques for a case study.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Programming & Computation: Python (SciPy, NumPy, DEAP, PyGMO), MATLAB Optimization Toolbox
- Visualization: Matplotlib, Plotly, MATLAB plots
- Spreadsheet Solver: Microsoft Excel Solver (LP and NLP)

Suggested Reading

Reference Books

- Kalyanmoy Deb, "Multi-Objective Optimization using Evolutionary Algorithms", Wiley, 2001.
- Hamdy A. Taha, "Operations Research: An Introduction", 10th Edition, Pearson, 2017.
- Gareth James et al., "An Introduction to Statistical Learning", Springer, 2021.

Additional Resources

- NPTEL: Engineering Optimization – IIT Kharagpur (https://nptel.ac.in)
- Coursera: "A Crash Course in Optimization" – University of Michigan

DLI Course Mapped

Fundamentals of Deep Learning: [https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+C-FX-01+V3](https://learn.nvidia.com/courses/course-detail?course_id=course-v1%3ADLI+C-FX-01+V3)

DLI Learning Path

- Deep Learning for Science and Engineering
- AI-Assisted Optimization Techniques
- Reinforcement Learning for Decision-Making

Applied Engineering Statistics and Process Optimization

(As per Choice Based Credit System)	
Course Code: 26MDE5306	**Semester:** III
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mathematics, Probability and Statistics, Basics of Manufacturing Processes	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course equip students with advanced statistical tools for analyzing complex engineering data. and to develop the ability to model, interpret, and improve engineering processes using data-driven approaches. This course enables the application of design of experiments and optimization techniques in real-world design problems. This course fosters critical thinking for decision-making under uncertainty in engineering systems. This course also prepares student for research and industry applications involving process optimization and performance enhancement.

Course Objectives

Students will be able to:

- Apply statistical concepts to engineering data analysis
- Understand probability and distributions in engineering
- Perform statistical inference and regression
- Design experiments for process improvement
- Apply optimization techniques in design engineering

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain probability distributions, sampling, estimation, and hypothesis-testing concepts used for statistical inference on	L2

CO	Course Outcome	BTL
	engineering data.	
CO2	Develop and interpret regression models for predicting engineering system behavior.	L4
CO3	Design and analyze experiments to optimize process parameters and improve performance.	L4
CO4	Formulate engineering optimization problems and solve them using linear programming techniques.	L3
CO5	Analyze nonlinear and constrained optimization problems using classical methods and heuristic techniques such as genetic algorithms for engineering design and process problems.	L4

Broad Course Description

This course focuses on the application of statistical methods and optimization techniques in engineering problems. It introduces probability theory, data analysis, and statistical inference for interpreting experimental data. Students learn regression modeling and correlation analysis to predict system behavior. The course emphasizes design of experiments for systematic investigation and process improvement. Optimization techniques are covered to enhance performance and efficiency in engineering systems. Practical applications in design engineering, manufacturing, and quality control are highlighted throughout. The course prepares students for data-driven decision-making and advanced research in engineering optimization.

Detailed Course Syllabus

Course Modules

Module 1: Statistical Inference – Engineering Applications (9 Hours)

Sampling techniques and estimation methods. Confidence intervals and hypothesis testing (t-test, chi-square, ANOVA). Error analysis and decision-making under uncertainty. Applications in process validation and experimental analysis.

Engineering Applications: *Process validation of machined-part dimensions using hypothesis tests, confidence-interval estimation of material tensile strength, and supplier-lot comparison using ANOVA.*

Module 2: Regression Analysis (9 Hours)

Simple and multiple linear regression models. Correlation analysis and model fitting techniques. Residual analysis and validation of regression models. Applications of regression models. Applications of model fitting techniques

Engineering Applications: *Regression models of tool wear versus cutting speed, surface-roughness prediction from machining parameters, and fatigue-life and failure-rate trend analysis.*

Module 3: Design of Experiments (DOE) (9 Hours)

Fundamentals and principles of experimental design including randomization, replication, and blocking. Full factorial and fractional factorial designs for studying multiple factors efficiently. Analysis of variance (ANOVA) for determining the significance of factors and interactions. Taguchi methods, orthogonal arrays, and signal-to-noise ratio for robust design. Response Surface Methodology (RSM) for modeling and optimization of processes. Application of DOE in process improvement, product development, and quality enhancement.

Engineering Applications: *Factorial and Taguchi studies of welding, machining, and injection-moulding parameters; response-surface optimization of surface finish and material removal rate; robust product design.*

Module 4: Optimization Techniques – Part I (9 Hours)

Introduction to optimization problems in engineering design and decision-making. Formulation of objective functions and constraints for real-world problems. Linear programming techniques including graphical and simplex methods.

Engineering Applications: *Product-mix and production planning in a machining shop, cutting-stock and resource allocation, and minimum-cost design under constraints using graphical and simplex formulations.*

Module 5: Optimization Techniques – Part II (9 Hours)

Nonlinear and constrained optimization methods using classical approaches. Introduction to modern optimization techniques such as genetic algorithms and heuristic methods. Applications in design optimization, resource allocation, and performance improvement of engineering systems.

Engineering Applications: *Minimum-weight design of springs and pressure vessels, genetic-algorithm-based process-parameter optimization, and constrained sizing of heat exchangers.*

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	1	3	–	2	1	–	–	–	–	–	–	–	2
CO2	2	2	3	2	1	–	–	–	–	–	–	–	–
CO3	2	3	3	2	1	–	–	–	–	–	–	2	–
CO4	2	1	3	–	1	–	–	–	–	–	–	2	3
CO5	2	1	3	–	1	–	–	–	–	–	–	2	3

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand how Artificial Intelligence and machine learning complement statistical methods for process modelling, quality control, and optimization in engineering applications.

Example Activities:

- Develop a machine-learning regression model to predict process output from process parameters and compare with classical regression.
- Apply AI-assisted anomaly detection for statistical process control (SPC) charts.
- Evaluate machine-learning-based design-of-experiments (DOE) strategies for process optimization.
- Simulate AI-assisted root-cause analysis for process variation using historical process data.
- Compare classical statistical process optimization with AI-driven predictive process optimization.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Data Handling & Visualization: Wolfram Alpha, MATLAB
- AI-Assisted Development Tools: ChatGPT, Grammarly

Suggested Reading

Reference Books

- Rao, Engineering Optimization, Laxmi publications., 4th Edition
- Ross, Statistics for Engineers, Mcgraw Hill publications, 5th edition
- Spiegel, Probability and Statistics, O'Reilly Media.

Additional Resources

- NPTEL: Courses on Engineering Statistics, DOE, and Optimization by IIT faculty.
- NPTEL: Applied Statistics for Engineers – IIT Kharagpur
- Minitab and JMP Statistical Software Documentation
- ASQ (American Society for Quality) Learning Resources

DLI Course Mapped

Fundamentals of Data Science https://learn.nvidia.com/

DLI Learning Path

- AI-Assisted Statistical Process Control
- Machine Learning for Process Optimization
- Data-Driven Quality Engineering

Structural Reliability and Failure Prevention Engineering

(As per Choice Based Credit System)	
Course Code: 26MDE5307	**Semester:** III
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Strength of Materials, Machine Design, Engineering Mechanics, Finite Element Analysis	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop advanced competency in structural reliability analysis and failure prevention engineering, covering uncertainty modelling, failure mechanisms, and reliability-based design methods. The course enables postgraduate learners to assess structural reliability, predict failure risks, and apply AI-assisted monitoring approaches for safe and reliable engineering design.

Course Objectives

Students will be able to:

- Gain knowledge of structural reliability concepts, uncertainty modeling, and probabilistic methods in engineering design.
- Understand various failure mechanisms in engineering structures and methods for failure prevention.
- Apply reliability analysis techniques for fatigue, fracture, creep, and corrosion failures in mechanical systems.
- Develop skills in reliability-based design, risk assessment, and maintenance planning.
- Make use of AI-assisted monitoring and predictive reliability approaches for structural health management.

Course Outcomes (CO)

CO	Course Outcome	BTL

CO	Course Outcome	BTL
CO1	Explain probabilistic concepts and uncertainty modeling techniques used in structural reliability analysis.	L2
CO2	Analyze different failure modes and mechanisms in engineering structures and components.	L4
CO3	Analyze the reliability of structural components under fatigue, fracture, creep, and corrosion loading using stress–strength interference and Weibull analysis.	L4
CO4	Apply reliability-based design and risk assessment methodologies to engineering systems.	L3
CO5	Apply AI-assisted predictive maintenance and structural health monitoring approaches for failure prevention.	L3

Broad Course Description

This course introduces the principles of structural reliability and engineering failure prevention for mechanical and structural systems. It covers probabilistic approaches for uncertainty quantification, reliability assessment, and risk-based design methodologies. The course discusses failure mechanisms including fatigue, fracture, creep, wear, and corrosion, along with methods for improving structural integrity and service life. Students gain knowledge in reliability-centered maintenance, condition monitoring, and AI-assisted predictive maintenance techniques for industrial applications. Practical engineering case studies are integrated throughout the course to develop analytical and decision-making skills for safe and sustainable engineering design.

Detailed Course Syllabus

Course Modules

Module 1: Fundamentals of Structural Reliability and Probability Concepts (9 Hours)

Introduction to structural reliability, deterministic and probabilistic approaches, random variables, probability distributions, statistical parameters, reliability function, hazard rate, probability of failure, uncertainty in loads and material properties, reliability index, limit state functions, safety factors, Monte Carlo simulation basics.

Engineering Applications: Reliability estimation of machine components, probabilistic load assessment in pressure vessels, uncertainty analysis in mechanical design systems.

Module 2: Failure Mechanisms in Engineering Structures (9 Hours)

Modes of structural failure, ductile and brittle fracture, fatigue failure, creep failure, corrosion and wear mechanisms, stress concentration effects, crack initiation and propagation, fracture mechanics

concepts, failure theories, root cause analysis and failure investigation techniques.

Engineering Applications: Failure analysis of turbine blades, pressure vessel crack assessment, fatigue failure investigation in automotive shafts, corrosion analysis in pipelines.

Module 3: Reliability Analysis of Structural Components (9 Hours)

Stress-strength interference theory, system reliability, series and parallel systems, fatigue reliability analysis, fracture reliability assessment, creep reliability, reliability under variable loading, reliability-based life prediction, Weibull analysis, reliability testing methods and data interpretation.

Engineering Applications: Reliability prediction of bearings and gears, fatigue life assessment of aircraft structures, creep reliability analysis in high-temperature components.

Module 4: Reliability-Based Design and Risk Assessment (9 Hours)

Reliability-based design optimization (RBDO), factor of safety and reliability relationships, design codes and standards, fault tree analysis, failure mode and effects analysis (FMEA), risk assessment techniques, maintenance strategies, reliability-centered maintenance (RCM), life-cycle cost analysis.

Engineering Applications: Risk-based inspection planning for industrial plants, reliability optimization of rotating machinery, maintenance planning for power plant systems.

Module 5: AI-Assisted Structural Health Monitoring and Failure Prevention (9 Hours)

Structural health monitoring (SHM), sensors and data acquisition systems, vibration-based fault diagnosis, condition monitoring techniques, predictive maintenance concepts, machine learning applications in reliability engineering, AI-assisted failure prediction, digital twins for structural reliability, smart maintenance systems.

Engineering Applications: AI-based predictive maintenance in manufacturing systems, sensor-based monitoring of bridges and rotating equipment, smart failure prevention systems in aerospace and automotive industries.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	3	–	–	2	–	–	–	–	–	–	–	3
CO2	2	3	–	–	2	–	–	–	–	–	–	–	3
CO3	2	2	–	–	1	–	–	–	–	–	–	–	3
CO4	2	2	3	–	1	–	–	–	–	–	–	1	2
CO5	2	–	2	–	3	2	–	–	–	–	–	–	3

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

Implement a probabilistic reliability model:

- Define random variables for load and strength
- Calculate probability distributions

- Estimate reliability index
- Interpret probability of failure

Develop a failure diagnosis system:

- Collect failure data
- Identify failure mechanisms
- Analyze crack growth trends
- Generate failure assessment reports

Implement reliability prediction using statistical tools:

- Perform Weibull analysis
- Estimate fatigue life
- Analyze reliability under variable loading
- Compare predicted and experimental life data

Develop a risk assessment framework:

- Identify critical failure modes

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Python
- ANSYS
- Minitab
- Weibull Analysis Software
- AI-Assisted Predictive Maintenance Platforms
- Vibration Analysis and Structural Health Monitoring Tools

Suggested Reading

Reference Books

- Probability Concepts in Engineering – Wiley Publications.
- Fracture Mechanics – CRC Press.
- Engineering Maintenance Management – CRC Press.
- Structural Health Monitoring – Wiley Publications.
- Reliability Engineering – Wiley Publications.

Additional Resources

- NPTEL Courses on Reliability Engineering
- Coursera – Predictive Maintenance and Reliability Engineering
- MIT OpenCourseWare – Structural Mechanics and Reliability
- ANSYS Learning Resources
- MATLAB Reliability and Predictive Analytics Documentation

DLI Course Mapped

AI for Predictive Maintenance and Reliability Engineering
https://learn.nvidia.com/

DLI Learning Path

- Artificial Intelligence and Industrial Digitalization
- AI-Assisted Reliability Prediction
- Predictive Maintenance and Risk Assessment

Dissertation – Phase II

(As per Choice Based Credit System)

Course Code: 26MDE5401	**Semester:** IV
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Dissertation – Phase I	
Course Type: Research Project	**Hours/Week:** 24 **Total Hours:** 360 Hrs (Project / Research Work) **Credits:** 12
L – T – P – J: 0 – 0 – 0 – 24	

Purpose and Scope

Dissertation / Research Project Phase II is the culmination of the postgraduate research or design work initiated in Phase I. The student shall carry out detailed analysis, design, simulation, experimentation, or development based on the methodology finalized in Phase I, and shall document, validate, and defend the complete body of work as the final M.Tech dissertation.

Course/Activity Objectives

Students will be able to:

- Execute the detailed research/design methodology finalized in Phase I to achieve the stated objectives.
- Apply advanced analytical, computational, or experimental techniques to generate and validate results.
- Critically analyse and interpret results with reference to existing literature and design/engineering standards.
- Demonstrate originality, technical rigor, and research/design maturity in the completed dissertation work.
- Document and defend the complete dissertation through a comprehensive report and oral examination.

Learning Outcomes

- Execute a complete research or design study from methodology to validated outcomes.
- Apply advanced analytical, computational, and/or experimental methods with technical rigor.
- Critically evaluate and interpret results in the context of the existing body of knowledge.
- Demonstrate independent research/design capability and problem-solving skills at the postgraduate level.
- Communicate original research/design contributions through a formal dissertation and defence.

Methodology / Work Plan

Building on the objectives, scope, and methodology finalized in Phase I, the student shall carry out the full-scale analytical, computational, or experimental investigation, including design iterations, validation against benchmarks or existing literature, and refinement of results. Regular guidance meetings with the supervisor shall continue throughout the semester to ensure technical rigor and timely progress.

Project / Research Milestones

- Milestone 1: Detailed design/analysis/experimentation based on Phase I methodology (Weeks 1–5).
- Milestone 2: Generation and validation of results (Weeks 6–10).
- Milestone 3: Result interpretation, optimization, and refinement (Weeks 11–14).
- Milestone 4: Compilation of the final dissertation report (Weeks 15–17).
- Milestone 5: Dissertation submission, presentation, and viva-voce (Weeks 18–20).

Review and Progress Evaluation

Progress shall be monitored through periodic review meetings with the supervisor and a minimum of two formal reviews before the Departmental Review Committee, assessing technical progress, validity of results, and readiness for final submission.

Expected Deliverables / Outcomes

- Complete and validated research/design results addressing the stated objectives.
- A comprehensive final dissertation report.
- Supporting technical artefacts such as models, simulations, drawings, prototypes, or datasets, as applicable.
- A research paper / technical article suitable for conference or journal submission (where applicable).

Report / Documentation Requirements

The student shall submit a complete Dissertation Report prepared in the format prescribed by the Department and University, including an abstract, introduction, literature review, methodology, results and discussion, conclusions, and references. The report shall demonstrate technical rigor, originality, and adherence to academic integrity and plagiarism norms as per University guidelines.

Presentation and Viva-Voce

The student shall present the complete dissertation work before an examination panel comprising the supervisor and external/internal examiners, followed by a comprehensive viva-voce examination assessing the technical depth, originality, and overall quality of the dissertation.

Duration and Workload

Dissertation / Research Project Phase II is carried out over Semester IV with an equivalent workload of 24 hours per week (360 hours total), corresponding to 12 credits, under continuous guidance from the allotted supervisor.

Assessment Scheme

– Assessment for Project Phase–II comprises Continuous Internal Assessment (CIA) carrying a weightage of 60%, assessed by the supervisor and the Departmental Review Committee, and External Evaluation / Viva-Voce carrying a weightage of 40%, as detailed in the tables below.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
Project Review–IV – Implementation / Development	Detailed implementation, fabrication, modelling, simulation or experimentation	Relevant COs (L3–L5)	15	Technical implementation, design development, experimental/simulation progress
Project Review–V – Results & Analysis	Results, analysis and validation	Relevant COs (L4–L5)	15	Analysis, interpretation, comparison, validation and discussion of results
Project Report & Pre-Final Presentation	Complete project documentation and presentation	Relevant COs (L4–L6)	15	Technical report, presentation, documentation and project outcomes
Supervisor Assessment	Continuous project work and contribution	Relevant COs	15	Regularity, initiative, technical contribution, problem solving and overall progress
Total Internal Assessment	Project Phase–II		60	Internal Assessment
External Evaluation / Viva-Voce	Complete project	All relevant COs	40	External presentation, defence, technical evaluation, results and project contribution
Grand Total	**Project Phase–II**		**100**	**60 Internal + 40 External**

External Evaluation / Viva-Voce Breakdown (100 → 40 Conversion)

Assessment Component	Coverage / Focus	COs (BTL)	Evaluation Marks	Converted Marks	Purpose / Assessment Criteria
Project	Overall	All relevant	20	8	Clarity of problem,

Presentation	project	COs			objectives, methodology, work carried out and outcomes
Technical Work & Implementation	Design / modelling / fabrication / simulation / experimentation	All relevant COs	25	10	Technical contribution, implementation quality and application of engineering knowledge
Results, Analysis & Validation	Results and project outcomes	All relevant COs	25	10	Analysis, interpretation, validation, comparison and technical justification
Project Report	Complete project documentation	All relevant COs	15	6	Technical documentation, organization, methodology, results and conclusions
Viva-Voce / Defence	Complete project	All relevant COs	15	6	Understanding of the work, response to questions, problem-solving ability and individual contribution
Total	**Complete Project**		**100**	**40**	**External Evaluation / Viva-Voce**

Machine Learning for Intelligent Engineering Systems

(As per Choice Based Credit System)	
Course Code: 26MDE5402	**Semester:** IV
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Engineering Mathematics, Basic Programming Knowledge, Fundamentals of Artificial Intelligence	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course develops the ability to apply machine learning techniques for intelligent engineering analysis, predictive modeling, optimization, and smart industrial applications. The learners gain knowledge in supervised and unsupervised learning algorithms, deep learning fundamentals, engineering data analytics, and AI-enabled intelligent systems for modern engineering applications.

To empower design engineers with the expertise to design integrated, intelligent material handling and automation systems that optimize industrial workflows through the synergy of mechanical design and cutting-edge digital intelligence

Course Objectives

Students will be able to:

- Analyze principles of industrial transport and the systematic classification of material handling equipment
- Impart technical know-how regarding the architectural components of industrial automation, including PLCs, SCADA, and Distributed Control Systems (DCS)
- Apply advanced control strategies for automated material handling systems such as AGVs and intelligent conveyor belts
- Integrate AI/ML techniques for predictive maintenance, self-optimization, and real-time decision-making in smart factory environments

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain supervised and unsupervised learning techniques and the machine learning workflow, including preprocessing and feature extraction, for engineering datasets.	L2
CO2	Apply neural network and deep learning models to engineering prediction and classification problems.	L3
CO3	Apply machine learning techniques to predictive maintenance, remaining useful life prediction, and quality inspection in intelligent engineering and manufacturing systems.	L3
CO4	Apply generative AI, evolutionary and genetic algorithms, and explainable-AI techniques to engineering design optimization.	L3
CO5	Analyze emerging trends in machine learning for engineering, including GPU-accelerated and edge-AI workflows, for intelligent automation.	L4

Broad Course Description

This course introduces students to the concepts and applications of machine learning for intelligent engineering systems. The course focuses on integrating data-driven methodologies, predictive analytics, and artificial intelligence techniques into engineering problem solving and industrial automation.

Learners will gain knowledge in engineering data preprocessing, supervised and unsupervised learning algorithms, deep learning fundamentals, neural network architectures, intelligent optimization techniques, and AI-enabled engineering workflows. The course also emphasizes engineering applications involving predictive maintenance, manufacturing analytics, structural monitoring, digital twins, and smart industrial systems.

Beyond conventional machine learning methods, the course introduces NVIDIA GPU-accelerated AI platforms and CUDA-enabled computing frameworks for large-scale engineering analytics and intelligent automation.

Through theoretical concepts, industrial case studies, and AI-assisted engineering approaches, the course nurtures the capability to develop intelligent systems for modern engineering industries and smart manufacturing environments.

This course provides a comprehensive exploration of material handling and industrial system automation, bridging mechanical design with electronic control systems. Students will study the selection and application of various equipment, including conveyors, industrial trucks, and hoisting appliances, integrated into a unified automation framework using PLCs, SCADA, and DCS.

The curriculum emphasizes the transformation toward smart manufacturing and Industry 4.0, incorporating technologies such as the Industrial Internet of Things (IIoT), digital twins, and cyber-physical systems. A significant portion of the course is dedicated to AI integration, where students

learn to use machine learning and predictive analytics to enhance system reliability and responsiveness.

Detailed Course Syllabus

Course Modules

Module 1: Supervised and Unsupervised Learning Techniques (9 Hours)

Regression and classification methods: Linear regression, Polynomial regression, Logistic regression, Decision trees, Random forests, Support Vector Machines, K-Nearest Neighbour algorithm. Unsupervised learning techniques: K-means clustering, Hierarchical clustering and Principal Component Analysis (PCA). Model evaluation metrics: Accuracy, Precision, Recall, F1-score, Cross-validation and Confusion matrix.

Engineering Applications: *Tool condition monitoring, Fault classification in rotating machinery.*

Module 2: Neural Networks and Deep Learning Fundamentals (9 Hours)

Artificial Neural Networks: Biological inspiration, Perceptron model, Activation functions, Forward propagation and Backpropagation concepts. Deep Learning Fundamentals: Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Hyperparameter tuning and optimization techniques. GPU-accelerated deep learning concepts using NVIDIA CUDA-enabled frameworks and TensorFlow GPU execution.

Engineering Applications: *Surface defect detection, Structural crack identification using AI-based image processing.*

Module 3: Machine Learning Applications in Intelligent Engineering Systems (9 Hours)

Predictive maintenance and intelligent monitoring systems, Sensor-based machine learning analytics, Vibration and thermal analysis using AI, Remaining useful life prediction. AI in manufacturing systems: Smart manufacturing, Process optimization, Quality inspection using machine learning, Intelligent scheduling and automation systems. Introduction to digital twins and Industrial Internet of Things (IIoT).

Engineering Applications: *CNC machine health prediction, Smart production line optimization.*

Module 4: Advanced AI Systems (9 Hours)

Generative AI concepts for engineering applications, AI-assisted engineering design optimization, Evolutionary algorithms, Genetic algorithms and Multi-objective optimization techniques. Explainable AI, Ethical considerations in AI systems, Sustainable AI practices, Industry 4.0 integration, Edge AI systems and future trends in intelligent engineering systems.

Engineering Applications: Generative design of lightweight components, genetic-algorithm-based design optimization, explainable AI for fault diagnosis, and edge-AI condition monitoring on the shop floor.

Module 5: Future Trends in Engineering (9 Hours)

Emerging trends in machine learning for intelligent engineering systems: GPU-accelerated machine learning workflows using NVIDIA CUDA-enabled platforms; physics-informed and hybrid data-driven models for engineering simulation; foundation models and large language models for engineering knowledge and design assistance; deployment of machine learning models on edge devices and model compression; MLOps overview: model deployment, monitoring, and lifecycle management in industrial settings; emerging application areas such as autonomous systems and smart infrastructure.

Engineering Applications: GPU-accelerated defect detection and inspection, physics-informed surrogate models for simulation, LLM-assisted engineering documentation and design support, and edge-deployed condition monitoring.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	1	–	3	–	–	–	–	–	–	–	2
CO2	2	3	–	2	1	–	–	–	–	–	–	–	2
CO3	2	–	3	–	3	–	–	–	–	–	–	–	3
CO4	2	2	2	–	3	–	–	–	–	–	–	1	3
CO5	2	–	3	–	3	–	–	–	–	–	–	–	2

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

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

The course incorporates NVIDIA-enabled AI and accelerated computing platforms to support intelligent engineering analytics, predictive modeling, deep learning workflows, and GPU-accelerated engineering simulations. Students are encouraged to make use of NVIDIA CUDA Toolkit, Omniverse, Nsight Systems, and AI-enabled engineering tools for real-time simulation, optimization, and intelligent automation applications.

AIM: Understand how machine learning and GPU-accelerated AI frameworks improve engineering analysis, prediction accuracy, and intelligent industrial decision-making.

Example: a. Import engineering datasets related to vibration and thermal monitoring.

- Preprocess and normalize engineering data using machine learning libraries.
- Develop a predictive maintenance model using supervised learning algorithms.
- Evaluate model performance using confusion matrix and accuracy metrics.
- Visualize prediction performance and interpret engineering significance using AI-assisted analysis tools.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Programming: Python, Google Colab, Jupyter Notebook
- AI Frameworks: TensorFlow, Keras, Scikit-learn
- Visualization: Matplotlib, Seaborn, Plotly
- Engineering AI Tools: MATLAB AI Toolbox, Ansys AI-assisted optimization tools
- NVIDIA CUDA Toolkit for GPU-accelerated machine learning applications
- NVIDIA Omniverse for AI-enabled engineering simulation and visualization

Suggested Reading

Primary Textbooks

- Ethem Alpaydin, “Introduction to Machine Learning”, MIT Press, Fourth Edition, 2020.
- S. Rajasekaran and G. A. Vijayalakshmi Pai, “Neural Networks, Fuzzy Logic and Genetic Algorithms”, PHI Learning, 2011.

Reference Books

- Ian Goodfellow, Yoshua Bengio and Aaron Courville, “Deep Learning”, MIT Press, 2016.
- Aurélien Géron, “Hands-On Machine Learning with Scikit-Learn, Keras and TensorFlow”, O’Reilly Media, Third Edition, 2022.
- Kevin P. Murphy, “Machine Learning: A Probabilistic Perspective”, MIT Press, 2012.
- Christopher M. Bishop, “Pattern Recognition and Machine Learning”, Springer.
- J.J. Craig, Introduction to Robotics: Mechanics and Control, Pearson Education, 2022.

Additional Resources

- NPTEL: Machine Learning and Artificial Intelligence Courses
- NVIDIA CUDA Documentation
- TensorFlow Official Documentation
- Scikit-learn Documentation
- NPTEL Course: "Industrial Automation and Control" (IIT Kharagpur/IISc)

DLI Course Mapped

Fundamentals of Deep Learning and Accelerated Computing
https://learn.nvidia.com/ Artificial Intelligence in Industrial Automation

DLI Learning Path

- Artificial Intelligence and Accelerated Computing
- Predictive Maintenance and Intelligent Monitoring Systems
- Machine Learning for Engineering Design and Manufacturing

Finite Element Applications in Structural Engineering

(As per Choice Based Credit System)	
Course Code: 26MDE5403	**Semester:** IV
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Fundamental knowledge of Solid Mechanics and Engineering Mathematics	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course enables the learner to apply finite element concepts to structural engineering problems involving buildings, bridges, plates, shells, and other load-bearing systems, with a focus on reliable interpretation, design relevance, and digital workflow integration.

Course Objectives

Students will be able to:

- Apply finite element idealization concepts for modeling structural members, assemblies, loads, constraints, and boundary conditions.
- Analyze trusses, beams, and frame structures using finite element formulations and matrix-based procedures.
- Evaluate slabs, plates, and shell-type structural systems using appropriate finite element discretization and response interpretation techniques.
- Assess stability, vibration, and nonlinear structural behavior using finite element analysis methods.
- Apply FE software workflows, scripting tools, and AI-enabled techniques for structural assessment and smart infrastructure applications.

Course Outcomes (CO)

CO	Course Outcome	BTL

CO	Course Outcome	BTL
CO1	Explain finite element idealization of structural systems, including degrees of freedom, loads, and boundary conditions.	L2
CO2	Analyze trusses, beams, and frame systems using finite element formulation, assembly procedures, and load applications.	L4
CO3	Analyze slabs, plates, and shell structures using appropriate mesh generation, element selection, and stress interpretation methods.	L4
CO4	Apply FE tools to determine the stability, dynamic response, and nonlinear behavior of structural systems.	L3
CO5	Analyze FE results and apply software, scripting, and AI-assisted workflows for structural engineering applications.	L4

Broad Course Description

The course presents the practical use of finite element analysis in structural engineering. It focuses on how idealized models are created from real structures, how load paths and restraints are represented, and how the resulting numerical output supports structural assessment and design. Students gain the ability to move from basic member models to full structural systems and to evaluate the implications of the computed response. The elective is suitable for postgraduate students who wish to strengthen analytical skills for building systems, bridges, machine supports, and other structural applications. The course emphasizes engineering judgment, numerical interpretation, and modern digital practices including AI-assisted analysis, data-driven decision support, and model updating.

Detailed Course Syllabus

Course Modules

Module 1: Structural Modeling and FE Idealization (9 Hours)

Review of structural idealization, degrees of freedom, load transfer, discretization strategy, element selection, coordinate systems, nodal connectivity, and modeling assumptions. Common sources of error in structural FE models, verification against analytical solutions, and interpretation of stiffness, flexibility, and constraint behavior.

Engineering Applications: load-bearing frames, floor systems, industrial supports, and structural subassemblies

Module 2: Analysis of Trusses, Beams, and Frames (9 Hours)

Finite element formulation and application to plane trusses, space trusses, beams, planar frames, and space frames. Support conditions, member releases, equivalent nodal loads, thermal loads, and

assembly of global matrices. Case studies on roof trusses, portal frames, and beam grillages.

Engineering Applications: roof trusses, portal frames, crane structures, beam grillages AI / Digital Tools: scripting of load cases and parametric structural studies using Python or MATLAB

Module 3: Slabs, Plates, and Shells in Structures (9 Hours)

Finite element idealization of slabs, plates, and shell-like structural systems. Membrane and bending action, boundary conditions, mesh choice, stress concentration, compatibility, and interpretation of deflection and stress contours. Introduction to composite structural panels and stiffened plates.

Engineering Applications: floor slabs, retaining panels, tank walls, bridge decks, plates with cut-outs

Module 4: Stability, Dynamics, and Nonlinear Response (9 Hours)

Buckling analysis of columns, frames, and plates; modal analysis of buildings and machine-supported structures; basic transient response; material and geometric nonlinearity; and introductory contact issues. Structural reliability checks under combined actions, serviceability, and performance-based analysis.

Engineering Applications: buckling assessment, vibration serviceability, seismic response screening, nonlinear support behavior

Module 5: Structural Applications, Software Workflow, and Smart Infrastructure (9 Hours)

Use of commercial and open-source FE tools for structural engineering workflows, including preprocessing, meshing, solver settings, post-processing, and reporting. Benchmark studies, load combinations, design implications, and documentation. Introduction to Industry 4.0 themes such as connected sensing, cloud-based analysis, and AI-enabled structural health monitoring.

Engineering Applications: buildings, bridges, towers, industrial platforms, retrofitting and assessment studies

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	–	–	1	–	–	–	–	–	–	–	2
CO2	2	3	1	–	2	–	–	–	–	–	–	–	3
CO3	2	3	–	–	3	–	–	–	–	–	–	–	3
CO4	2	3	–	–	3	–	–	–	–	–	–	–	3
CO5	2	3	1	–	3	–	–	–	–	–	–	–	2

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand how Artificial Intelligence and data-driven techniques can complement finite element analysis by predicting structural response, classifying damage states, and supporting

digital-twin-based structural health monitoring.

Example Activities:

- Generate a small training set from FE simulations and fit a regression model to predict displacement or stress.
- Use vibration response data to classify damage states or support conditions.
- Compare FE outputs with AI predictions and discuss error, robustness, and interpretability.
- Build a simple digital-twin style workflow in which sensor inputs update a structural response model.

AI-Integrated Lab Exercises (Indicative)

- Use a lightweight regression model to predict displacement or stress from a small set of design variables and compare the prediction with FE output.
- Develop a data-driven post-processing workflow for automated interpretation of structural response trends.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- FE and structural software: ANSYS, Abaqus, ETABS, STAAD.Pro, OpenSees, or equivalent.
- Programming and analytics: Python, MATLAB, and spreadsheet-based verification.
- AI tools: scikit-learn, basic deep learning libraries, and cloud notebook environments.

Suggested Reading

Reference Books

- S. S. Bhavikatti, Finite Element Analysis, New Age International.
- O. C. Zienkiewicz, R. L. Taylor and J. Z. Zhu, The Finite Element Method: Its Basis and Fundamentals, Elsevier.
- C. S. Krishnamoorthy, Finite Element Analysis: Theory and Programming, Tata McGraw-Hill.

Additional Resources

- NPTEL modules on structural finite element analysis.
- Vendor manuals and benchmark examples from structural FE software packages.
- MIT OpenCourseWare – Finite Element Analysis of Solids and Structures

DLI Course Mapped

Fundamentals of Accelerated Computing with CUDA C/C++
https://learn.nvidia.com/

DLI Learning Path

- Accelerated Computing for Finite Element Analysis

Material Handling and Industrial System Automation

(As per Choice Based Credit System)	
Course Code: 26MDE5404	**Semester:** IV
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Industrial Engineering Fundamentals, Manufacturing Processes, Basics of Automation and Control Systems	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course provides postgraduate students with an in-depth understanding of material handling systems and industrial automation technologies used in modern manufacturing and logistics operations. The course enables learners to design, select, and integrate automated material handling equipment and control systems for efficient, safe, and intelligent industrial operations aligned with Industry 4.0 practices.

Course Objectives

Students will be able to:

- Analyse the principles of industrial material transport and the systematic classification of material handling equipment and systems.
- Design and select appropriate material handling equipment such as conveyors, AGVs, and AS/RS for a given industrial application.
- Apply programmable logic control (PLC) and automation principles to industrial material handling and production systems.
- Evaluate robotic systems and their integration into automated material handling and assembly operations.
- Integrate IIoT and data-driven approaches for real-time monitoring, predictive maintenance, and optimization of automated material handling systems.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain the classification, selection criteria, and design principles of material handling equipment and the levels of industrial automation.	L2
CO2	Apply design and selection principles of conveyor systems, AGVs, and AS/RS to material transport in industrial facilities.	L3
CO3	Apply PLC programming, SCADA, and industrial networking concepts to the control of material handling and production systems.	L3
CO4	Apply robot kinematics, trajectory planning, and hoisting-appliance principles to robotic and lifting operations in automated material handling.	L3
CO5	Analyze IIoT-enabled smart material handling and cyber-physical systems for predictive maintenance, cybersecurity, and real-time monitoring.	L4

Broad Course Description

This course provides a comprehensive treatment of material handling systems and industrial automation technologies used in modern manufacturing, warehousing, and logistics operations. It covers the classification and design of manual, mechanized, and automated material handling equipment, along with the automation architectures that control them.

Learners will study programmable logic controllers (PLCs), industrial robotics, conveyor systems, automated guided vehicles (AGVs), and automated storage and retrieval systems (AS/RS), with emphasis on system design, selection, and integration for efficient material flow.

The course further introduces Industrial Internet of Things (IIoT) concepts for connecting material handling and automation systems to enterprise platforms, enabling real-time monitoring, predictive maintenance, and data-driven decision-making aligned with Industry 4.0 practices.

Detailed Course Syllabus

Course Modules

Module 1: Introduction to Material Handling & Automation Fundamentals (9 Hours)

Core Topics: Classification and economics of material handling systems, unit load concepts, plant layout and workflow analysis, principles of material handling, selection criteria for handling equipment, levels of industrial automation (fixed programmable, flexible, integrated automation).

Engineering Applications: Material flow optimization in manufacturing industries, handling systems for process industries, warehouses, and smart factories, industrial case studies on automated handling systems.

Module 2: Conveyor Systems & Automated Guided Vehicles (AGVs) (9 Hours)

Core Topics: Belt, chain, roller, screw, bucket, and pneumatic conveyors, conveyor design considerations, AGV architecture and navigation methods, fleet management systems, automated storage and retrieval systems (AS/RS).

Engineering Applications: Smart warehouse automation, airport baggage handling, automotive assembly lines, logistics and distribution systems.

Module 3: Industrial Control Architectures (PLC & SCADA) (9 Hours)

Core Topics: PLC hardware architecture, ladder logic programming, timers, counters, and sequencers, SCADA systems and communication protocols, Distributed Control Systems (DCS), industrial networking and IIoT integration.

Engineering Applications: Industrial process monitoring, water treatment automation, power plant supervision, manufacturing execution systems.

Module 4: Robotics & Hoisting Appliances in Automation (9 Hours)

Core Topics: Robot configurations and kinematics, trajectory planning, end effectors and grippers, hoisting appliances including cranes, elevators, winches, and grab buckets, safety in robotic handling systems.

Engineering Applications: Automated welding and assembly; robotic palletizing; underwater and hazardous-environment handling; heavy-material lifting systems.

Module 5: Smart Manufacturing & Cyber-Physical Systems (9 Hours)

Core Topics: Industry 4.0 concepts, Industrial Internet of Things (IIoT), digital twins, cyber-physical systems, predictive maintenance, industrial cybersecurity, sustainable and energy-efficient manufacturing systems.

Engineering Applications: Smart factories, intelligent energy management, digital production monitoring, predictive maintenance in critical infrastructure.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	3	3	–	1	–	–	–	–	–	–	2	3
CO2	2	3	–	–	1	–	–	–	–	–	–	–	3
CO3	3	–	2	–	1	–	–	–	–	–	–	1	2
CO4	2	3	–	–	1	–	–	–	–	–	–	–	3
CO5	2	3	–	–	2	–	–	–	–	–	–	–	3

AI Integration & Authentic Intelligence Reflection (AI^2 Pedagogy)

AIM: Understand how Artificial Intelligence and machine learning improve the efficiency, safety, and adaptability of material handling and industrial automation systems.

Example Activities:

- Develop a machine-learning model to predict conveyor/AGV traffic patterns and optimize material flow in a warehouse layout.
- Simulate AI-assisted path planning for automated guided vehicles (AGVs) in a material handling facility.
- Evaluate predictive maintenance models for material handling equipment such as cranes and conveyors using sensor data.
- Analyse computer-vision-based object detection for automated sorting and palletizing systems.
- Compare rule-based and AI-based scheduling strategies for industrial automation systems.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Suggested Reading

Primary Textbooks

- Fred E. Meyers and Matthew P. Stephens, Manufacturing Facilities Design and Material Handling, Pearson, 5th Edition, 2013.
- Mikell P. Groover, Automation, Production Systems, and Computer-Integrated Manufacturing, Pearson, 4th Edition, 2015.

Reference Books

- James M. Apple, Plant Layout and Material Handling, Wiley, 3rd Edition.
- Saeed B. Niku, Introduction to Robotics: Analysis, Control, Applications, Wiley, 3rd Edition, 2019.
- R. K. Rajput, Industrial Engineering and Management, S. Chand Publishing.

Additional Resources

- NPTEL: Material Handling Systems – IIT Kharagpur
- NPTEL: Industrial Robotics – IIT Kanpur
- IEEE Papers on Industrial IoT and Smart Material Handling Systems

DLI Course Mapped

Fundamentals of Accelerated Computing for Industrial Automation
https://learn.nvidia.com/

DLI Learning Path

- Industrial Automation Fundamentals
- Robotics for Material Handling
- Smart Warehousing and AS/RS Systems
- IIoT for Industrial Systems

Computational Fracture and Damage Mechanics

(As per Choice Based Credit System)	
Course Code: 26MDE5405	**Semester:** IV
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Advanced Solid Mechanics, Finite Element Methods, Basic Programming Knowledge	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop advanced competency in the computational modelling of fracture and damage in engineering materials and structures, using finite element and simulation-based methods to predict crack initiation, propagation, and failure for reliable and safe mechanical design.

Course Objectives

Students will be able to:

- Understand fundamental and computational approaches to fracture and damage mechanics.
- Apply finite element methods to evaluate stress intensity factors and crack-tip fields.
- Apply cohesive zone and extended finite element method (XFEM) techniques for crack propagation modelling.
- Evaluate continuum damage mechanics models for progressive failure in ductile and composite materials.
- Use simulation software and AI-assisted tools to predict fracture behaviour and remaining life of engineering components.

Course Outcomes (CO)

CO	Course Outcome	BTL
CO1	Explain linear elastic fracture mechanics concepts and the computational approaches used to determine stress intensity factors	L2

CO	Course Outcome	BTL
	and crack-tip stress fields.	
CO2	Apply J-integral, CTOD, cohesive zone, and XFEM techniques to model elastic-plastic fracture and crack propagation.	L3
CO3	Analyze continuum damage mechanics models for progressive failure in ductile and composite materials.	L4
CO4	Apply Paris-law, crack-closure, retardation, and probabilistic fracture mechanics models to estimate the residual life of components.	L3
CO5	Analyze fracture behaviour and remaining life of components using simulation software and AI-assisted tools.	L4

Broad Course Description

This course introduces computational methods for analysing fracture and damage in engineering materials and structures, building on classical fracture mechanics to cover finite-element-based crack analysis, cohesive zone modelling, and continuum damage mechanics. The course emphasizes the prediction of crack initiation, propagation, and failure using modern simulation tools.

Learners will gain exposure to:

- Linear and elastic-plastic fracture mechanics
- Finite element modelling of cracks and singular fields
- Cohesive zone and XFEM-based crack propagation
- Continuum damage mechanics and AI-assisted life prediction

Detailed Course Syllabus

Course Modules

Module 1: Computational Linear Elastic Fracture Mechanics (09 Hours)

Review of stress intensity factor and energy release rate concepts, finite element modelling of cracked bodies, singular and quarter-point crack-tip elements, J-integral and virtual crack closure technique (VCCT) for numerical evaluation of fracture parameters, mixed-mode fracture criteria, mesh refinement and convergence for crack-tip stress fields.

Engineering Applications: *Pressure vessels, aircraft fuselage panels, pipelines, welded structural joints.*

Module 2: Elastic-Plastic Fracture and Crack Propagation Modelling (09 Hours)

Elastic-plastic fracture mechanics: crack-tip opening displacement (CTOD), J-integral for nonlinear

materials, HRR field. Computational crack propagation: cohesive zone modelling (CZM), traction-separation laws, extended finite element method (XFEM) for arbitrary crack growth, element deletion and node release techniques, fatigue crack growth simulation using Paris law-based crack advancement.

Engineering Applications: *Automotive structural components, offshore structures, gear root cracking, weld toe fatigue cracking.*

Module 3: Continuum Damage Mechanics (09 Hours)

Concepts of damage variables and effective stress, isotropic and anisotropic damage models, ductile damage and void growth models (Gurson-Tvergaard-Needleman), damage evolution laws, coupling of damage with plasticity, progressive damage and failure modelling in composite laminates, application of damage mechanics in finite element software.

Engineering Applications: *Automotive crash components, composite aircraft structures, forming and metal-cutting simulations.*

Module 4: Fatigue Crack Growth and Probabilistic Fracture Mechanics (9 Hours)

Fatigue crack growth: Paris law, threshold and near-threshold behaviour, crack closure effects, variable amplitude loading and retardation models (Wheeler, Willenborg), residual life estimation using the fracture mechanics approach. Probabilistic fracture mechanics: statistical scatter in fracture toughness and crack growth data, reliability-based fracture assessment, Monte Carlo simulation for probability of failure, introduction to risk-based inspection and damage-tolerant design philosophy.

Engineering Applications: *Aircraft damage-tolerant design, pressure vessel and pipeline inspection intervals, offshore structure reliability assessment, railway axle fatigue life prediction.*

Module 5: AI-Assisted Fracture Prediction and Digital Health Monitoring (9 Hours)

Introduction to data-driven and machine-learning-based fracture and fatigue life prediction, surrogate modelling for crack growth simulation, AI-assisted defect and crack detection from simulation and sensor data, digital twin concepts for structural health monitoring, case studies integrating simulation and AI for remaining useful life estimation.

Engineering Applications: *Aerospace structural health monitoring, wind turbine blade damage assessment, pipeline integrity management, automotive fatigue-critical components.*

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	3	–	–	–	3	–	–	–	–	–	–	–	2
CO2	1	–	–	–	2	–	–	–	–	–	–	–	2
CO3	2	3	–	–	2	–	–	–	–	–	–	–	3

CO4	1	2	–	–	2	–	–	–	–	–	–	–	3
CO5	2	–	–	–	3	–	–	–	–	–	–	–	2

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand how Artificial Intelligence and machine learning methods accelerate fracture-parameter prediction, damage assessment, and remaining-life estimation in computational fracture mechanics.

Example Activities:

- Develop a machine-learning surrogate model to predict stress intensity factors from crack geometry and loading parameters.
- Apply AI-assisted image analysis to detect and quantify cracks from simulated or experimental images.
- Evaluate machine-learning-based fatigue crack growth prediction using Paris-law-generated datasets.
- Simulate AI-assisted damage classification (matrix cracking, delamination, void growth) from finite element output data.
- Compare conventional fracture-mechanics-based life prediction with AI-assisted digital-twin-based remaining-useful-life estimation.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Suggested Reading

Primary Textbooks

- T. L. Anderson, Fracture Mechanics: Fundamentals and Applications, CRC Press, 4th Edition, 2017.
- Jian-Bo Zang and Zhuo Zhuang, Extended Finite Element Method, Tsinghua University Press/Academic Press, 2012.

Reference Books

- Jean Lemaitre and Jean-Louis Chaboche, Mechanics of Solid Materials, Cambridge University Press, 1994.
- David Broek, Elementary Engineering Fracture Mechanics, Springer, 4th Edition, 1986.
- N. E. Dowling, Mechanical Behavior of Materials, Pearson, 5th Edition, 2019.

Additional Resources

- NPTEL – Computational Fracture Mechanics
- NPTEL – Damage Mechanics and Life Prediction
- ANSYS Fracture and XFEM Tutorials
- MIT OpenCourseWare – Fracture and Fatigue
- ASTM Standards for Fracture Toughness Testing (E399, E1820)

DLI Course Mapped

NPTEL – Computational Fracture Mechanics https://nptel.ac.in

DLI Learning Path

- AI-Assisted Fracture and Fatigue Prediction
- Digital Twin-Based Structural Health Monitoring
- Computational Damage Mechanics
- Intelligent Structural Integrity Assessment

Industry 4.0 and Smart Manufacturing Integration

(As per Choice Based Credit System)	
Course Code: 26MDE5406	**Semester:** IV
Programs Offered: M.Tech – Design Engineering	
Prerequisites: Manufacturing Processes, Industrial Automation, Basics of IoT and Cyber-Physical Systems	
Course Type: Professional Elective (PEC)	**Hours/Week:** 03 **Total Hours:** 45 Hrs Theory **Credits:** 03
L – T – P – J: 3 – 0 – 0 – 0	

Course Vision

This course aims to develop a strong understanding of Industry 4.0 concepts and smart manufacturing technologies, enabling students to design, integrate, and optimize intelligent, connected industrial production systems.

Course Objectives

Students will be able to:

- Explain the core concepts, drivers, and enabling technologies of Industry 4.0 and smart manufacturing.
- Analyse industrial automation and communication systems used in integrated manufacturing.
- Apply Industrial Internet of Things (IIoT) and cyber-physical systems concepts to smart factory design.
- Evaluate data analytics and digital manufacturing techniques for process monitoring and optimization.
- Design smart factory and sustainable manufacturing systems aligned with Industry 4.0 practices.

Course Outcomes (CO)

CO	Course Outcome	BTL

CO	Course Outcome	BTL
CO1	Explain the concepts, architecture, and enabling technologies of Industry 4.0 and smart manufacturing.	L2
CO2	Apply industrial automation and communication systems for integrated manufacturing operations.	L3
CO3	Analyze Industrial Internet of Things (IIoT) architectures and cyber-physical systems for smart factories.	L4
CO4	Apply data analytics and digital manufacturing techniques for process monitoring and optimization.	L3
CO5	Analyze smart factory and sustainable manufacturing systems for Industry 4.0-enabled production.	L4

Broad Course Description

This course introduces Industry 4.0 technologies and smart manufacturing systems with emphasis on industrial automation and intelligent production environments. It covers automation systems, sensors, industrial communication, Industrial Internet of Things (IIoT), cyber-physical systems, cloud manufacturing, industrial data analytics, and smart factory technologies. Students gain exposure to modern manufacturing trends and sustainable industrial operations through engineering-oriented case studies and applications.

Detailed Course Syllabus

Course Modules

Module 1: Introduction to Industry 4.0 and Smart Manufacturing (9 Hours)

Industrial revolutions, introduction to Industry 4.0, smart manufacturing concepts, digital transformation in industries, intelligent production systems, smart factories, fundamentals of automation, advantages and challenges of Industry 4.0.

Engineering Applications: Smart production monitoring system, automated manufacturing line, digital factory operations.

Module 2: Industrial Automation and Communication Systems (9 Hours)

Industrial sensors and actuators, programmable logic controllers (PLC), supervisory control and data acquisition (SCADA), industrial robots, industrial communication protocols, wireless communication in industries, machine-to-machine communication.

Engineering Applications: Automated conveyor system, robotic material handling system, industrial monitoring and control system.

Module 3: Industrial Internet of Things (IIoT) and Cyber-Physical Systems (9 Hours)

Introduction to IIoT, smart sensors, embedded systems in manufacturing, cyber-physical systems, cloud manufacturing, edge computing concepts, industrial networking, real-time monitoring systems.

Engineering Applications: Remote equipment monitoring system, smart energy management system, connected manufacturing devices.

Module 4: Data Analytics and Digital Manufacturing (9 Hours)

Industrial data collection, manufacturing data analysis, predictive maintenance concepts, digital twin concepts, additive manufacturing, simulation in manufacturing, artificial intelligence applications in manufacturing, quality monitoring systems.

Engineering Applications: Predictive maintenance system, production data analysis system, quality inspection and monitoring system.

Module 5: Smart Factory and Sustainable Manufacturing Systems (9 Hours)

Smart factory architecture, sustainable manufacturing, energy-efficient production systems, supply chain digitization, cybersecurity in manufacturing, future trends in Industry 4.0, intelligent manufacturing ecosystems.

Engineering Applications: Smart warehouse system, intelligent supply chain monitoring, energy-efficient manufacturing operations.

Strength of CO Mapping to POs / PSOs

COs	Program Outcomes (POs)											PSOs	
COs	1	2	3	4	5	6	7	8	9	10	11	1	2
CO1	2	–	2	–	2	–	–	–	–	–	–	1	3
CO2	1	–	–	–	1	–	–	–	–	1	–	1	2
CO3	3	3	3	–	1	–	–	–	–	–	–	–	3
CO4	3	3	2	2	2	–	–	–	–	–	–	1	3
CO5	2	3	3	–	3	–	2	–	–	–	–	2	3

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

AI Integration & Authentic Intelligence Reflection (AI² Pedagogy)

AIM: Understand how Artificial Intelligence, IIoT, and data-driven approaches enable smart manufacturing and Industry 4.0 integration.

Example Activities:

- Use AI-supported analytics tools to study sensor data from a simulated smart factory process line.
- Investigate AI-based predictive maintenance models for manufacturing equipment using historical operating data.

- Apply data-driven approaches to evaluate energy efficiency, productivity, and sustainability of a digital manufacturing system.

Assessment Scheme

– "Internal Assessment" refers to the Continuous Internal Assessment (CIA), carrying a weightage of 60%. It comprises CAT–1, Mid-Semester Examination (MSE), CAT–2, and CAT–3, distributed across the five course modules and aligned with the relevant Course Outcomes (COs) and Bloom's Taxonomy Levels (BTL).

– "External Assessment" refers to the Semester End Examination (SEE), carrying a weightage of 40%, covering the comprehensive syllabus.

Assessment Component	Coverage / Focus	COs (BTL)	Marks	Purpose / Possible Assessment Methods
CAT–1 – Understand	Module 1	CO1 / CO2 (L1–L2)	10	Knowledge, understanding and interpretation. Written Test / Quiz / Assignment / Concept-based Questions / Case Study
Mid-Sem Examination (MSE)	Modules 2 & 3	CO2 / CO3 (L2–L4)	40 → 30	Knowledge, understanding, application, analysis and problem solving. Written Examination
CAT–2 – Apply	Module 4	CO3 / CO4 (L2–L3)	10	Application and problem solving. Problem-solving / Numerical Exercise / Coding / Assignment / Case Study
CAT–3 – Analyze	Module 5	CO4 / CO5 (L2–L4)	10	Analysis, interpretation, comparison and problem decomposition. Case Study / Problem Analysis / Technical Assignment / Application-based Test / Mini Activity
Total CIA	Modules 1–5	—	**60**	—
SEE	Comprehensive Syllabus	As applicable	**40**	End-Semester Examination
Grand Total	—	—	**100**	—

Recommended Tools

- Analytical Calculation: Scientific calculator, Excel / Google Sheets
- Programming / Computation: MATLAB / Python / GNU Octave
- Simulation Tools: MATLAB/Simulink, AnyLogic, Siemens Plant Simulation, NVIDIA Omniverse

- Design Documentation: MS Word / LaTeX / Google Docs
- AI-Assisted Learning Tools: ChatGPT, GitHub Copilot, WolframAlpha, IIoT analytics platforms

Suggested Reading

Primary Textbooks

- Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things, Apress.
- Rajiv Suman, Industry 4.0 and Smart Manufacturing, CRC Press.
- S. Vaidya, P. Ambad, S. Bhosle, Industry 4.0 – A Glimpse, Procedia Manufacturing / Elsevier.

Reference Books

- Klaus Schwab, The Fourth Industrial Revolution, Crown Business.
- Alp Ustundag and Emre Cevikcan, Industry 4.0: Managing The Digital Transformation, Springer.
- Jay Lee, Industrial AI: Applications with Sustainable Performance, Springer.
- Sabina Jeschke et al., Industrial Internet of Things: Cybermanufacturing Systems, Springer.
- M. Ozdemir and I. Hekimoglu, Digital Transformation and Smart Manufacturing, IntechOpen.

Additional Resources

- NPTEL – Industry 4.0 and Industrial Internet of Things
- NPTEL – Smart Manufacturing Systems
- NPTEL – Industrial Automation and Control

DLI Course Mapped

Fundamentals of Accelerated Computing – AI for Engineering Design and Simulation
https://learn.nvidia.com/

DLI Learning Path

- Accelerated Computing
- Industrial Digitalization and Smart Manufacturing
- AI for Production Systems