MECHANICAL ENGINEERING

M.Tech

Engineering Design

DEPARTMENT OF MECHANICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI,620015
TAMIL NADU,INDIA

NATIONAL INSTITUTE OF TECHNOLOGY: TIRUCHIRAPPALLI – 620 015

DEPARTMENT OF MECHANICAL ENGINEERING

M. Tech. Engineering Design

The total minimum credits required for completing the **M. Tech. Programme** in Mechanical Engineering is **80**.

Vision of the Institute

- To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

Mission of the Institute

- To offer undergraduate, postgraduate, doctoral and modular Programme in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically.

Vision of the Department

- To be a globally renowned Department in Mechanical Engineering where the best of teaching, learning and research synergize to fulfil the requirements of industry and society.

Mission of the Department

The Mechanical Engineering Department is committed to:

- Prepare effective and responsible engineers for global requirements by providing quality education through graduate, post graduate and doctoral research Programmes.
- Constantly strive to improve the teaching and learning processes by adopting innovative pedagogical methods.
- Respond effectively to the needs of the industry and society by offering sustainable and innovative solutions.
- Conduct basic and interdisciplinary research to publish in reputed international journals and to generate intellectual property.
- Provide consultancy services and cultivate the spirit of entrepreneurship.

Programme Outcomes (POs)

PO1	Ability to independently carry out research / investigation to solve practical problems.
PO2	Ability to write and present technical reports/documents.
PO3	Demonstrate mastery in Engineering Design beyond UG level.

CURRICULUM

Semester I

Sl. No.	Course Code	Course of Study	Credits
1	ME601	Mathematical Methods	4
2	ME701	Advanced Mechanics of Solids	4
3	ME703	Finite Element Method in Engineering Design	4
4		Programme Elective – I	4
5		Programme Elective – II	3
6		Programme Elective – III	3
7	ME707	Computer Aided Design and Analysis Lab	2
		Total	**24**

Semester II

Sl. No.	Course Code	Course of Study	Credits
1	ME702	Mechanical Vibrations & Acoustics	4
2	ME704	Mechanics of Composite Materials	4
3	ME706	Experimental Stress Analysis	4
4		Programme Elective – IV	4
5		Programme Elective – V	3
6		Programme Elective – VI	3
7	ME708	Mechanical Design Lab	2
		Total	**24**

Summer Term (Evaluation in the III Semester)

Sl. No.	Course Code	Course of Study	Credits
1	ME744	Internship / Industrial Training / Academic Attachment (I / A) (6 weeks to 8 weeks)	**2**

Semester III

Sl. No.	Course Code	Course of Study	Credits
1	ME745	Project Work (Phase I)	**12**

Semester IV

Sl. No.	Course Code	Course of Study	Credits
1	ME746	Project Work (Phase II)	**12**

Open Electives (OE) / Online Course (OC)

Sl. No.	Course Code	Course of Study	Credits
1		# (To be completed between I to IV semester)	**6**

COURSE DISTRIBUTION

Type of Course	No.
Programme Core (PC)	**6**
Essential Laboratory Requirements (ELR)	**2**
Programme Elective (PE)	**29**
Design & Manufacturing Focus	16
Automotive Engineering Focus	03
Aerospace Engineering Focus	04
Cross-Cutting & Advanced Topics	06
Online Courses – NPTEL	**20**
Total Courses	**57**

LIST OF PROGRAMME CORE (PC) COURSES

Sl. No.	Course Code	Course of Study	Credits
1.	ME601	Mathematical Methods	4
2.	ME701	Advanced Mechanics of Solids	4
3.	ME703	Finite Element Method in Engineering Design	4
4.	ME702	Mechanical Vibrations & Acoustics	4
5.	ME704	Mechanics of Composite Materials	4
6.	ME706	Experimental Stress Analysis	4

LIST OF ESSENTIAL LABORATORY REQUIREMENT (ELR) COURSES

Sl. No.	Course Code	Course of Study	Credits
1.	ME707	Computer Aided Design and Analysis Lab	2
2.	ME708	Mechanical Design Lab	2

LIST OF PROGRAMME ELECTIVE (PE) COURSES

DESIGN & MANUFACTURING FOCUS

Sl. No.	Course Code	Course of Study	Credits
1.	ME710	Product Design and Development	4
2.	ME711	Design for Fatigue and Fracture	4
3.	ME712	Computer Aided Design	3
4.	ME713	AI & ML in Mechanical Engineering	3
5.	ME714	Design for Manufacturing & Assembly	3
6.	ME715	Machine Tool Design	4
7.	ME716	Theory of Plasticity	3
8.	ME717	Continuum Mechanics	3
9.	ME718	Smart Materials and Structures	3
10.	ME719	Advanced Robotics	3
11.	ME720	Advanced Mechanisms Design	3
12.	ME721	Digital Manufacturing & Industry 5.0	3
13.	ME722	MEMS: Design, Fabrication and Characterization	4
14.	ME723	Tribology in Design	3
15.	ME724	Reverse Engineering	3
16.	ME725	Drone Technology	3

AUTOMOTIVE ENGINEERING FOCUS

Sl. No.	Course Code	Course of Study	Credits
1.	ME726	Automotive Chassis & Body Engineering	3
2.	ME727	Vehicle Dynamics & Control	3
3.	ME728	Electric & Hybrid Vehicle Engineering	3

AEROSPACE ENGINEERING FOCUS

Sl. No.	Course Code	Course of Study	Credits
1.	ME729	Advanced Flight Dynamics & Stability	3
2.	ME730	Composite Materials for Aerospace	3
3.	ME731	Computational Fluid Dynamics for Aerospace Applications	3
4.	ME732	Finite Element Analysis for Aerospace	3

CROSS CUTTING & ADVANCED TOPICS

Sl. No.	Course Code	Course of Study	Credits
1.	ME733	Multibody System Dynamics	4
2.	ME734	Optimization Techniques in Mechanical Engineering	3
3.	ME735	Mechatronic System Design	3
4.	ME736	Corrosion Engineering & Design	3
5.	ME737	Non-destructive Evaluation	3
6.	ME738	Topology Optimization and Generative design	3

LIST OF OPEN ELECTIVE (OE) COURSES

Sl. No.	Course Code	Course of Study	Credits
1.	ME713	AI & ML in Mechanical Engineering	3
2.	ME734	Optimization Techniques in Mechanical Engineering	3
3.	ME737	Non-destructive Evaluation	3

SYLLABUS

PROGRAMME CORE COURSES

Course Code	:	ME601
Course Title	:	**Mathematical Methods**
Type of Course	:	Programme Core (PC)
Prerequisites	:	NIL
Contact Hours	:	4
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the numerical methods for solving various equations in engineering field.
CLO2	To compute numerical methods for solving ODEs and PDEs
CLO3	To develop own code/scripts for the different numerical schemes
CLO4	To execute curve fitting and regression analysis
CLO5	To solve boundary and initial value problems.

Course Content

Introduction: Numerical precision in digital computing and its effect on numerical calculations, Taylor series and truncation, Rounding off errors, Introduction to Programming.

System of Equations and Eigen values: Review of solution methods to system of linear equations, Computation of Eigen values, solution of algebraic equations (univariate and multivariate non-linear equations, root finding and optimization), Well-conditioned and ill conditioned system, Matrix and vector norms.

Interpolation, differentiation and integration: Interpolation (polynomial, Lagrange interpolation, error estimates, piecewise polynomial, Hermite, Spline, 2D (rectangle and triangle)), Curve Fitting/Regression, Numerical Differentiation, Numerical Integration (Simpson's rule, Guass Quadrature)

Ordinary Differential Equations: Initial value problems (Euler Method, RK methods, Predictor corrector methods), Boundary Value Problems (Shooting method, FDM, FEM, Weighted residuals, FVM).

Partial Differential Equations - Introduction to PDEs, classification of PDEs, Numerical solutions methods, Laplace and Poisson Equations, Iterative methods (Jacobi, Gauss Seidel, steepest decent and conjugate gradient) Coding the iterative methods in MATLAB/C++/Fortran.

References

1.	S. P. Venkateshan and Prasanna Swaminathan, *Computational Methods in Engineering*, Springer, 2023
2.	Steven C. Chapra and Raymond P. Canale, *Numerical Methods for Engineers*, Mc-Graw Hill Education, Eighth Edition, 2021
3.	Joe D Hoffman, *Numerical Methods for Engineers and Scientists*, Second Edition and Expanded, Marcel. Dekker, 2001.

4.	Gilbert Strang, *Computational Science and Engineering*, Wellesley-Cambridge Press, 2007

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Numerically compute solution of system of equations through Programming.
CO2	Compute numerical solution for ODE and PDE using coding.
CO3	Evaluate various iterative methods using computer Programming.
CO4	Perform curve fitting and regression analysis.
CO5	Solve boundary value problem and initial value problem numerically.

Course Code	:	ME701
Course Title	:	**Advanced Mechanics of Solids**
Type of Course	:	Programme Core (PC)
Prerequisites	:	NIL
Contact Hours	:	4
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart concept of stress and strain analysis in solids.
CLO2	To familiarize with 2D problems in elasticity and their solutions.
CLO3	To imbibe knowledge of elastic problems in polar coordinates.
CLO4	To acquaint with the solution of advanced bending problems.
CLO5	To understand torsional problems in elasticity.

Course Content

Strain: Tensor notations - Displacement field – engineering strain – strain tensor – Strain-displacement relations – Compatibility conditions – Strain transformation – Principal strains and planes. Stress: Stress at a point – Traction vector and Stress tensor – Stress components in rectangular coordinate systems – Cauchy's equations. Stress transformation – Principal stresses and planes – Hydrostatic and deviatoric stress components – Octahedral stress – Equations of equilibrium.

Constitutive Relations: Generalized Hooke's law – Stress-Strain relations for isotropic materials – Elastic constants – Relation between elastic constants - anisotropy. Saint-Venant's principle for end effects – General theorems of uniqueness, Linear superposition, and reciprocity – Castigliano's Theorem. Thermoelastic behavior of materials.

2D Elasticity: Plane stress and plane strain problems – Stress compatibility equation – Airy's stress function and equation – Polynomial method of solution – Solution for bending of a cantilever beam with an end load.

Elastic Problems in Polar Coordinates: Analogy between polar and rectangular coordinates – Equilibrium equations – Airy's stress function in polar coordinates – Application in Stress Concentration problems – Axisymmetric problems – Plate with a hole – Thick-walled cylinder and rotating discs.

Unsymmetrical Bending: Unsymmetrical bending of straight beams – Curved beams – Shear center of thin-walled open sections with one axis of symmetry. Torsion: Torsion of non-circular bars – Solutions for circular and elliptical cross-sections using Saint-Venant's theory and Prandtl's method – Torsion of thin-walled tubes – Shear flow.

References

1.	Timoshenko, S. and Goodier J.N., *Theory of Elasticity*. Tata McGraw-Hill, 2019
2.	Boresi, A.P., Schmidt, R.J. and Sidebottom, O.M., *Advanced Mechanics of Materials*, Wiley Publications, Sixth Edition, An Indian Adaption, 2020.
3.	Martin H. Sadd, *Elasticity: Theory, Applications, and Numerics*, Elsevier Academic Press, 2010.
4.	Srinath, L.S, *Advanced Mechanics of Solids*. Tata McGraw-Hill, Third Edition, 2008.

5.	Dym, C.L. and Shames, I.H., *Solid Mechanics: A Variational Approach*. Augmented Edition, Springer, 2013.
6.	Popov, E.P., *Engineering Mechanics of Solids*. Pearson Education India. Second Edition, 2015.

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To apply concepts of stress and strain analyses in solids.
CO2	To understand the effects of temperature change in elastic materials.
CO3	To formulate and solve 2D problems in elasticity.
CO4	To estimate the stress field in axisymmetric problems.
CO5	To solve general bending and torsion problems.

Course Code	:	ME703
Course Title	:	**Finite Element Method in Engineering Design**
Type of Course	:	Programme Core (PC)
Prerequisites	:	NIL
Contact Hours	:	4
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To Understand the concepts behind variational methods and weighted residual methods in FEM.
CLO2	To Identify the application and characteristics of FEA elements such as bar, Beam elements, and some heat transfer problems
CLO3	To learn the theory and characteristics of finite elements that represent engineering structures
CLO4	To implement Numerical Techniques and master isoparametric mapping, further, to understand the concepts of convergence, completeness, and how to estimate and minimize modeling
CLO5	To identify how the finite element method expands beyond the structural domain, for problems involving dynamics, also, to gain experience with commercial FEA software

Course Content

Introduction: Illustration using spring systems and simple problems, Variational formulation and Weighted residual methods.

1-D finite element analysis: truss element, beam element, frame element. Introduction to Heat transfer problems.

2-D finite element analysis: types of elements, shape functions, PASCAL triangle, Local and natural coordinate systems. Applications to structural mechanics – Plane stress element, plane strain element, axisymmetric element, plate bending element.

Numerical integration: Solution of finite element equations, error analysis, mesh refinement, continuity and convergence. 3-D finite element analysis: Solid and Isoparametric Elements

Dynamics problems in structural mechanics. Pre-processors, Post-processors and finite element packages.

Reference Books

1.	Cook, R.D., D.S. Malkus, M.E. Plesha and R.J. Witt, *Concepts and Applications of Finite Element Analysis*, John Wiley, Fourth Edition, 2001.
2.	J. N. Reddy, *An introduction to the Finite Element Method*, 3rd edition, McGraw-Hill, 2006.
3.	O. C. Zienkiewicz and R. L. Taylor, *The Finite Element Method*, 7th edition, Butterworth-Heinemann, 2013.
4.	Segerlind, L.J., *Applied Finite Element Analysis*, John Wiley, 1991.
5.	Hughes, T. J. R.,*The Finite Element Method: Linear Static and Dynamic Finite Element Analysis*, Dover Publications, 2003
6.	K. J. Bathe, *Finite Element Procedures in Engineering Analysis*, 2nd edition (reprint), Prentice-Hall, 2014.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Understand the concepts behind variational methods and weighted residual methods in FEM.
CO2	Identify the application and characteristics of FEA elements such as bar, beam elements and simple heat transfer problems
CO3	Develop element characteristic equation procedure and generation of global stiffness equation will be applied for different structural mechanics problems
CO4	Implementation of Numerical Techniques and mastering isoparametric mapping in various engineering problems and understand the concepts of convergence and completeness
CO5	Identify how the finite element method expands beyond the structural domain, for problems involving dynamics and gain experience with commercial FEA software for problem solving

Course Code	:	ME702
Course Title	:	**Mechanical Vibration and Acoustics**
Type of Course	:	Programme Core (PC)
Prerequisites	:	NIL
Contact Hours	:	4
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

CLO1	To understand the fundamentals of vibration.
CLO2	To develop the two degrees of freedom systems.
CLO3	To formulate the multi degree of freedom systems.
CLO4	To develop the governing equations for continuous systems.
CLO5	To impart knowledge on acoustics and its control.

Course Content

Fundamentals of Vibrations: Harmonic and periodic motions, Vibration terminology, Equations of motion - Energy method - Rayleigh method - Damping models - Viscously damped free vibration, Forced harmonic vibration - Magnification factor – Transmissibility. Vibration under general forcing conditions.

Two degrees of freedom system: Normal mode analysis – Translational system - Rotor system - Lagrangian energy method - Coordinate coupling.

Multi degree of freedom system: Close-coupled and far-coupled systems. Eigen value and vector - Linear system - Matrix method, Numerical methods - Dunkerley's formula, Rayleigh's Method, Holzer's method.

Vibration of continuous systems: Transverse vibration of strings, Longitudinal vibration of rods, Torsional vibration of shafts, Euler equations for beams.

Fundamentals of acoustics: Plane wave, propagation, radiation and scattering, Effect of noise on human, Acoustics measurement techniques, Vibration and Noise reduction methods.

References

1.	Thomson, W.T., *Theory of Vibration and its Applications*, 5th Edition, Prentice Hall, New Delhi, 2010.
2.	Rao, S.S., *Mechanical Vibrations*, 5th Edition, Pearson Education Inc. Delhi 2017.
3.	Malcolm J. Crocker, Jorge P. Arenas., *Engineering Acoustics: Noise and Vibration Control*, John Wiley & Sons, 2021.
4.	Jerry H. Ginsberg, *Acoustics: A Textbook for Engineers and Physicists Vol. I: Fundamentals*, Springer, 2018.
5.	Frank J. Fahy, *Foundations of Engineering Acoustics*, Academic Press, First Edition, 2000

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Review the fundamentals of vibration and formulate the differential equations of the given vibration models.
CO2	Develop the equation of motion for the two degrees of freedom system.
CO3	Model the equation of motion for the multi degrees of freedom system based on various numerical methods.
CO4	Formulate the governing equations for continuous systems.
CO5	Apply the acoustics measurement techniques and noise reduction methods to machineries.

Course Code	:	ME704
Course Title	:	**Mechanics of Composite Materials**
Type of Course	:	Programme Core (PC)
Prerequisites	:	NIL
Contact Hours	:	4
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives

CLO1	To understand the fundamentals of composite materials behavior.
CLO2	To impart knowledge on micromechanics of composite materials.
CLO3	To analyze the laminate stress-strain relations using CLT.
CLO4	To develop the governing equations for different laminates.
CLO5	To study the failure criteria for various laminates.

Course Content

Classification and characteristics of composite materials: Types of fiber and resin materials, functions and their properties – Application of composite materials.

Micromechanics: Mechanics of materials-Rule of Mixtures, Elasticity approaches-Mass and volume fraction of fibers and resins-Effect of voids, Effect of temperature and moisture.

Micromechanical behaviour of a Laminate: Classical Lamination Theory (CLT) – Lamina stress-strain behaviour – Interlaminar stresses- Special cases - Case studies.

Governing equations for Bending: Buckling-Vibration of laminated beam and plates, Case Studies.

Failure Criteria: - Failure Theory of Composites, Case Studies, Flexural rigidity of Sandwich beams and plates.

References

1.	R.M. Jones, *Mechanics of Composite Materials*, 2nd Edition, Taylor & Francis, ebook, 2018.
2.	L.R. Calcote, *The Analysis of laminated structures*, Van Nostrand Reinhold Co., 1969.
3.	AK Kaw. *Mechanics of Composite Materials*, 2nd Edition, CRC Taylor & Francis, New York, 2005.
4.	B.D. Agarwal and L.J. Broutman, *Analysis and Performance of fiber composites*, John-Wiley and Sons, Third Edition, 2006.
5.	Daniel, Isaac M., Ori Ishai, Issac M. Daniel, and Ishai Daniel, *Engineering mechanics of composite materials*. Oxford university press, 2006.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Classify and characterize the composite materials.
CO2	Apply the micromechanics approach to evaluate the composite materials properties.
CO3	Analyze the different composite laminates based on classical laminate theory (CLT).
CO4	Formulate the governing equations for bending, buckling, vibration of laminated plates.
CO5	Apply the failure criteria of composite laminates.

Course Code	:	ME706
Course Title	:	**Experimental Stress analysis**
Type of Course	:	Programme Core (PC)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To identify and distinguish various methods for stress/strain measurement
CLO2	To Recognize the various techniques available to measure the strains using different sources.
CLO3	To realize the working of recording instruments and data logging methods
CLO4	To distinguish the principles of photo elasticity in stress analyses
CLO5	To understand 'Stress Analysis' in a complete sense

Course Content

Analysis of stress and strain – basic equations of elasticity. Strain Measurement- an ideal strain gauge - mechanical, optical, acoustical, pneumatic, dielectric and electrical strain gauges.

Electrical Wire Resistance Strain Gauges: various types of gauges, materials, bonding agents, adhesives. Fixing of gauges, Temperature effects in bonded gauges, Gauge factor and gauge sensitivity.

Measurement of stress and stress gauge. Measuring Circuits and Strain Gauge Rosette: Potentiometer circuit, Wheatstone bridge, circuit sensitivity and output, temperature compensation and signal addition. Rectangular, delta and tee- delta rosette.

Analysis of Photoelasticity Data, polariscope, fringes due to principal stress direction and difference, model making, interpretation of isoclinics and isochromatics and fractional fringe order. Calibration through tension, beam and disc models - Reflection polariscopy. Brittle coating, crack pattern and crack detection in coating

Application to stress concentration and stress intensity factor - Separation of stresses.

References

1.	K. Ramesh, *e-Book on Experimental Stress Analysis*, IIT Madras, 2009.
2.	W. Dally and W. P. Riley, *Experimental Stress Analysis*, McGraw-Hill Book Co., 1991
3.	L. S. Srinath, M. R. Raghavan, *Experimental Stress Analysis*, Tata McGraw-Hill.1984
4.	Abdul Mubeen, *Experimental Stress Analysis*, Dhanpat Rai and Sons, 2001

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Understand the overall concepts of stress/strain analysis by experimental means
CO2	Mount strain gauges, design gauge-based transducers, and perform temperature compensation.
CO3	Interpret strain gauge data to analyze stress and conduct failure analysis.

CO4	Apply photoelasticity techniques for stress analysis and use other optical methods
CO5	Understand the techniques for determining the localized stress

LABORATORY COURSES

Course Code	:	ME707
Course Title	:	**Computer Aided Design and Analysis Lab**
Type of Course	:	ELR
Prerequisites	:	Nil
Contact Hours	:	2
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Develop advanced 3D modelling skills using modern CAD tools
CLO2	Apply engineering analysis using CAE software
CLO3	Integrate design and simulation for product development
CLO4	Interpret analysis results and optimize designs
CLO5	Gain exposure to real-world design workflows

List of Experiments

Computer Aided Design

Drafting and GD&T - Generation of 2D drawings from 3D models, Dimensioning standards, Geometric Dimensioning & Tolerancing (GD&T), BOM (Bill of Materials) creation.

Advanced Part Modelling - Parametric modelling and design intent, Complex features (lofts, sweeps, blends), Surface modelling techniques, Sheet metal design.

Assembly Modelling - Bottom-up and top-down assembly design, Mates and constraints, Interference and collision detection and Assembly motion study.

Motion Analysis - Mechanism creation (slider-crank, gear system), Application of joints and motion drivers, Kinematic analysis (displacement, velocity, acceleration), Visualization of motion.

Reverse Engineering - Import of scanned data (STL/point cloud), Surface reconstruction, Feature extraction, CAD model recreation from scan data. Digital Twin Modeling and Simulation.

Finite Element Analysis (FEA)

Structural Analysis - Geometry import and meshing, Boundary conditions and loads, Stress, strain, and deformation analysis, Result interpretation and validation.

Thermal Analysis - Steady-state thermal analysis, Heat transfer (conduction, convection basics), Temperature distribution and heat flux.

Modal Analysis - Natural frequency extraction, Mode shapes visualization, Application in vibration control.

Fatigue Analysis - Life cycle estimation, Stress-life (S-N curve) approach, Factor of safety under cyclic loading.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Create 2D drawings with proper dimensioning and GD&T.
CO2	Develop parametric 3D models using advanced modelling techniques.
CO3	Build assemblies and perform motion analysis of mechanisms.
CO4	Reconstruct CAD models using reverse engineering methods.
CO5	Apply FEA to evaluate structural, thermal, modal, and fatigue behaviour.

Course Code	:	ME708
Course Title	:	**Mechanical Design Lab**
Type of Course	:	ELR
Prerequisites	:	Nil
Contact Hours	:	2
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the behavior of a material under Vibration
CLO2	To determine the stress-strain curve of a mild steel under uniaxial loading using Extensometer
CLO3	To study the mechanical properties of materials when subjected to different types of loading.
CLO4	To analyze the tribo-characteristics of a material under sliding wear condition
CLO5	To understand the material deformation under constant stress condition.

List of Experiments

1. Translational Vibration of Single DOF system
2. Torsional Vibration of Single DOF system
3. Whirling of Shaft – Critical Speed Evaluation
4. Determination of stress/strain curve of mild steel using Extensometer
5. Bending stress analysis of a beam using experimental vs theoretical comparison
6. Strain measurement under combined loading using Stain gauge
7. Fatigue life estimation using Tension-Tension fatigue test
    a. S-N curve generation
    b. Fracture studies
8. Wear loss measurement using Pin-on-disc tester
9. Study on material deformation under constant stress using Creep testing machine
10. Validation of Simulation results with Experimental data.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Understand how the physical properties of a material such as stiffness, mass, and damping respond to dynamic forces.
CO2	Measure of precise strain in the elastic region during tensile loading of a mild steel rod.
CO3	Determines how materials behave under stress, ensuring structural integrity and guiding material selection in engineering design
CO4	Evaluate the frictional response, wear resistance, and the mechanisms of material loss when subjected to relative motion against a counter face
CO5	Demonstrate the time-dependent, slow and permanent (plastic) deformation of a material when subjected to a constant load or stress over an extended period.

PROGRAMMEME ELECTIVE COURSES

1. Design & Manufacturing Focus

Course Code	:	ME710
Course Title	:	**Product Design and Development**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	Nil
Contact Hours	:	4
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To develop advanced understanding of product design methodologies
CLO2	To integrate research, analysis, and engineering tools in product development
CLO3	To enable independent design thinking and innovation
CLO4	To apply simulation, optimization, and prototyping in real-world problems
CLO5	To understand the sustainability in product design and development

Course Content

Advanced Product Development Process - Product strategies and innovation frameworks, Product life cycle management (PLM), Concurrent and collaborative engineering, Design thinking and need identification, Research methods in product design.

Customer-Centric Design - Voice of Customer (VOC) methods, Quality Function Deployment (QFD), Kano model for customer satisfaction, Product Design Specifications (PDS), Benchmarking and competitive analysis.

Concept Generation & Selection - Creativity methods (TRIZ, bio-inspired design), Morphological analysis and concept synthesis, Multi-criteria decision-making (MCDM), Pugh matrix and evaluation methods, Product architecture and modular design.

Engineering Design Integration - Design for X (DFM, DFA, DfAM), CAD–CAE integration, Simulation-driven design and FEA basics, Material selection (Ashby approach), Tolerancing, reliability, robust design.

Prototyping & Product Realization - Rapid and additive manufacturing, Virtual prototyping and digital twins, Design validation and testing, Cost analysis and value engineering, Sustainability and lifecycle assessment.

Introduction to Soft Skills - Effective Communication, Teamwork & Collaboration, Adaptability, Critical Thinking, Emotional Intelligence and Time Management.

References

1.	Karl T. Ulrich, Steven D. Eppinger, Maria C. Yang, *Product Design and Development*, McGraw-Hill, 7th Edition, 2020.
2.	Gerhard Pahl, Wolfgang Beitz, Jörg Feldhusen, Karl-Heinrich Grote, *Engineering Design: A Systematic Approach*, Springer, 3rd Edition, 2007.
3.	Stuart Pugh, *Total Design: Integrated Methods for Successful Product Engineering*, Addison-Wesley, 1990.

4.	Geoffrey Boothroyd, Peter Dewhurst, Winston A. Knight, *Product Design for Manufacture and Assembly*, CRC Press, 3rd Edition, 2010.
5.	Michael F. Ashby, *Materials Selection in Mechanical Design*, Elsevier, 5th Edition, 2016
6.	A. K. Chitale, R. C. Gupta, *Product Design and Development*, PHI Learning Pvt. Ltd, 5th Edition, 2011.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Apply advanced product development processes.
CO2	Convert customer needs into design specifications.
CO3	Generate and evaluate design concepts.
CO4	Integrate CAD/CAE and DfX in design.
CO5	Develop and validate sustainable product solutions.

Course Code	:	ME711
Course Title	:	**Design for Fatigue and Fracture**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	4
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce the basic concepts of fracture mechanics.
CLO2	To impart knowledge on linear elastic fracture mechanics.
CLO3	To understand the behavior of materials undergoing elastic plastic fracture.
CLO4	To be familiarized with fatigue failure in engineering materials.Digi
CLO5	To study crack propagation under fatigue loading.

Course Content

Fracture Mechanics: History, Types of fracture, Modes of loading, Types of cracks, Classification of fracture mechanics – LEFM and EPFM, Solution of fracture mechanics problems – damage tolerance, Applications of fracture mechanics.

Linear Elastic Fracture Mechanics (LEFM): Griffith theory – Energy release rate (G). Stress analysis of cracks – Stress intensity factor (K), Relationship between K and G, Crack tip plasticity, Mixed mode crack propagation. Experimental determination of plane strain fracture toughness (K_{Ic}).

Elastic Plastic Fracture Mechanics (EPFM): Crack tip opening displacement (CTOD) – CTOD testing, Relationship between K and CTOD, CTOD Design curve. J-integral – Nonlinear energy release rate, Relationship between J and CTOD, J measurement.

Fatigue of Structures: Introduction to fatigue failure, Types of fatigue – High/Low Cycle, Thermal, Corrosion, Vibration/Acoustic, Contact/Fretting, and creep fatigue. S-N curves, Endurance limit, Effect of mean stress, Goodman, Gerber and Soderberg relations and diagrams, Effect of notches and stress concentrations.

Fatigue crack propagation: Constant amplitude cyclic loading – Paris law and Forman's equation. Crack closure phenomenon, Retardation of crack growth due to overloads. Variable amplitude cyclic loading.

References

1.	Anderson, T.L., *Fracture Mechanics: Fundamentals and Applications*. CRC Press. Third Edition, 2005.
2.	Broek, D., *Elementary Engineering Fracture Mechanics*. Springer Science & Business Media. 1982.
3.	Kumar, P., *Elements of Fracture Mechanics*. McGraw-Hill Education LLC. 2009.
4.	Simha, K.R.Y., *Fracture Mechanics for Modern Engineering Design*. Universities Press (India) Limited. 2001.
5.	Suresh, S., *Fatigue of Materials*. Cambridge University Press. Second Edition, 2012.
6.	Barsom, J.M. and Rolfe, S.T., *Fracture and Fatigue Control in Structures: Applications of Fracture Mechanics.* ASTM International. 1999.

7.	Dowling, N.E., Kampe, S.L. and Kral, M.V., *Mechanical Behavior of Materials: Engineering Methods for Deformation, Fracture, and Fatigue*. Pearson Education Limited. Fifth Edition, 2020.

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To apply the concept of linear elastic fracture mechanics in real world problems.
CO2	To solve structural mechanics problems involving elastic plastic fracture.
CO3	To know how the plane strain fracture toughness experiments are carried out for engineering materials.
CO4	To understand the behavior of engineering structures undergoing fatigue loading.
CO5	To evaluate the cycle life of structures against fatigue crack propagation.

Course Code	:	ME712
Course Title	:	**Computer Aided Design**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide advanced knowledge in computer aided geometric modeling and engineering graphics.
CLO2	To develop skills in mathematical representation of curves, surfaces, and solids used in CAD systems.
CLO3	To understand finite element modeling and integration of CAD with CAE/CAM environments.
CLO4	To expose students to modern CAD tools, product data management, and optimization techniques.
CLO5	To enable students to apply CAD concepts in engineering design and product development.

<u>Course Content</u>

Fundamentals of Computer Aided Design and Computer Graphics: Introduction to CAD, Product Development Process, Computer Graphics Fundamentals, Geometric Transformations, Viewing and Projection

Geometric Modeling Techniques: Introduction to Geometric Modeling, Mathematical Representation of Curves, Surface Modeling, Solid Modeling Techniques, Geometric Modeling Applications.

Advanced Solid Modeling and Assembly Modeling: Feature-Based Modeling, Advanced Solid Modeling, Assembly Modeling, Tolerance and Dimensioning, Product Data Management.

CAD Integration with CAE and CAM: CAD-CAE Integration, Finite Element Modeling in CAD, Design Optimization, CAD-CAM Integration, Reverse Engineering and Rapid Prototyping.

Applications of CAD in Engineering Design: CAD Applications in Mechanical Engineering, CAD in Manufacturing and Industrial Design, Computer Aided Engineering Trends, Design Validation and Product Realization.

References

1.	Ibrahim Zeid, *Mastering CAD/CAM*, Tata McGraw-Hill Education, Second Edition, 2006.
2.	Mikell P. Groover and Emory W. Zimmers, *CAD/CAM: Computer Aided Design and Manufacturing*, Pearson Education, First Edition, 2003.
3.	P. N. Rao, *CAD/CAM: Principles and Applications*, McGraw-Hill Education, Third Edition, 2017
4.	Donald Hearn and M. Pauline Baker, *Computer Graphics with OpenGL*, Pearson Education, Fourth Edition, 2014.

5.	Rogers D. F. and Adams J. A., *Mathematical Elements for Computer Graphics*, McGraw-Hill, Second Edition, 2017.
6.	Kuang-Hua Chang, *e-Design: Computer-Aided Engineering Design*, Academic Press, First Edition, 2015.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Explain the fundamentals of CAD systems, geometric transformations, and computer graphics concepts used in engineering design.
CO2	Develop mathematical models of curves, surfaces, and solid geometries for engineering applications.
CO3	Apply advanced solid modeling and assembly modeling techniques using modern CAD software.
CO4	Integrate CAD with finite element analysis, optimization, and manufacturing systems.
CO5	Design and analyze engineering components using CAD/CAE tools for industrial product development.

Course Code	:	ME713
Course Title	:	**AI & ML in Mechanical Engineering**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize students with the fundamentals of artificial intelligence and machine learning concepts relevant to engineering design
CLO2	To make students understand data-driven modeling and its role in design optimization and decision-making
CLO3	To make students learn various machine learning algorithms and their application in engineering problems
CLO4	To make students apply AI/ML techniques for design automation, prediction, and optimization
CLO5	To make students understand the integration of AI/ML with modern engineering design tools and industrial applications

Course Content

Introduction to AI and ML in Mechanical Engineering: Overview of artificial intelligence and machine learning, types of learning (supervised, unsupervised, reinforcement learning), role of AI in modern engineering design, data-driven design paradigm - Deep learning - Artificial Neural Networks (ANNs)**,** Recurrent Neural Networks (RNNs)**,** Long Short-Term Memory networks (LSTMs) and Gated Recurrent Units (GRUs).

Data handling and preprocessing: Types of engineering data, data collection, data cleaning, feature extraction and selection, normalization and dimensionality reduction techniques, introduction to datasets in engineering applications

Machine learning algorithms: Regression methods (linear, polynomial), classification techniques (k-nearest neighbors, support vector machines, decision trees), clustering methods (k-means, hierarchical clustering), model evaluation and validation

AI/ML in design and optimization: Surrogate modeling, response surface methods, genetic algorithms, neural networks in design optimization, multi-objective optimization, sensitivity analysis and uncertainty quantification

Applications in Mechanical Engineering: Predictive maintenance, fault diagnosis, material design and discovery, structural health monitoring, generative design, digital twins and smart manufacturing, case studies from mechanical and allied engineering domains

References

1.	Bishop C.M., *Pattern Recognition and Machine Learning*, Springer, 2006
2.	Goodfellow I., Bengio Y. and Courville A., *Deep Learning*, MIT Press, 2016.
3.	Mitchell T.M., *Machine Learning*, McGraw Hill, 1997
4.	Géron A., *Hands-On Machine Learning with Scikit-Learn, Keras, and Tensor Flow,* O'Reilly, Third Edition, 2022

5.	Deb K., *Optimization for Engineering Design: Algorithms and Examples*, PHI Learning, Second Edition, 2012
6.	Rao S.S., Engineering Optimization: Theory and Practice, Wiley, Fourth Edition, 2009

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To explain fundamental concepts of artificial intelligence and machine learning in engineering design
CO2	To process and analyze engineering data for building predictive models
CO3	To apply machine learning algorithms to solve engineering design problems
CO4	To develop AI/ML-based solutions for design optimization and automation
CO5	To evaluate and implement AI/ML techniques in real-world engineering applications

Course Code	:	ME714
Course Title	:	**Design for Manufacturing & Assembly**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize with DFM (manufacturing) methodologies for minimizing costs and complexity
CLO2	To select appropriate materials for machinability based on design requirements
CLO3	To enable selection of optimal materials and metal forming processes based on functionality and manufacturability.
CLO4	To identify a suitable welding process for meeting out the design guidelines
CLO5	To improve assembly efficiency through manual and automated design considerations.

Course Content

Introduction: Design Philosophy - steps in design process - General design rules for manufacturabilty - Basic principles of designing for economical production-creativity in design. Materials: Selection of materials for design - Developments in materials technology - Criteria for materials selection - Relationship with process selection.

Design for machining: Introduction to machining, Recommended materials for machinability, Design recommendation - Dimensional tolerance and surface roughness

Metal Forming: General design considerations for rolling, extrusion, stamping, casting and forging

Metal Joining: Appraisal of various welding processes, Factors in design of weldments - general design guidelines

Introduction to Assembly: The assembly process in manual and automation, Characteristics and applications, common assembly, Assembling a product, Design for Assembly: Introduction, Design consideration, design for robot assembly, Design for manufacture and Computer aided design.

References

1.	George E. Dieter, *Engineering Design - A material processing approach*, 5/e, McGraw Hill International, 2003.
2.	M F Ashby and K Johnson, *Materials and Design - the art and science of material selection in product design*, Butterworth-Heinemann, 2013.
3.	O. Molloy, S. Tilley and E.A. Warman, *Design for Manufacturing and assembly*, First Edition, Chapman &Hall, London, UK, First Edition, 1998.
4.	A K Chitale and R C Gupta, *Product Design and Manufacturing*, Prentice Hall of India, New Delhi, Fifth Edition, 2011.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Understand and evaluate quality and cost aspects of product design towards its manufacture.
CO2	Selection of suitable materials and methods to optimize design variables and improve machinability.
CO3	Integrate DFM principles in forming processes for component design.
CO4	Analyze and identify key design variables of various welding processes for aligning them with product development.
CO5	Apply automation and manual assembly techniques to enhance production reliability and efficiency.

Course Code	:	ME715
Course Title	:	**Machine Tool Design**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	4
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the fundamentals, kinematics, and design considerations of machine tools.
CLO2	Analyze and design machine tool structures and guideway systems considering stiffness and vibration behavior
CLO3	Design machine tool transmission systems and select suitable power transmission components.
CLO4	Evaluate dynamic behavior and vibration characteristics of machine tools and understand CNC-related design aspects
CLO5	Apply advanced concepts and modern tools in the design and optimization of intelligent machine tool systems

Course Content

Fundamentals of Machine Tool Design: Introduction to Machine Tools, Machine Tool Drives, Kinematics of Machine Tools, Machine Tool Design Criteria, Materials for Machine Tool Structures

Design of Machine Tool Structures: Machine Tool Beds and Columns, Structural Analysis, Guideways, Spindle Design, Machine Tool Joints.

Design of Power Transmission Elements: Gear Drives in Machine Tools, Belt and Chain Drives, Couplings and Clutches, Bearings for Machine Tools, Ball Screws and Feed Mechanisms.

Dynamics and Control of Machine Tools: Machine Tool Vibrations, Chatter Theory, Dynamic Analysis, Thermal Effects in Machine Tools, CNC Machine Tool Concepts.

Advanced Machine Tool Design and Applications: Design for Precision and Accuracy, High-Speed Machine Tools, Smart and Intelligent Machine Tools, Finite Element Analysis in Machine Tool Design, AM- based machine tools, Hybrid Manufacturing Systems, Digital Twin technology and Sustainable Machine Tool design.

Laboratory / Practical Components

1. Speed gearbox design using CAD
2. Feed gearbox kinematic analysis
3. Spindle deflection analysis
4. Guideway friction and wear study
5. Vibration analysis of machine tool structure
6. Bearing selection and life calculation
7. FEM analysis of machine tool bed
8. CNC machine tool component study

References

1.	N. Acherkan and N. Lisitsyn, *Machine Tool Design*, 1st Edition, Mir Publishers, Moscow, 2000
2.	N. K. Mehta, *Machine Tool Design*, 3rd Edition, Tata McGraw Hill Education Pvt. Ltd., New Delhi, Third Edition, 2012.
3.	Saroj Kumar Basu and D. K. Pal, *Design of Machine Tools*, 4th Reprint Edition, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi, Fifth Edition, 1995.
4.	Central Manufacturing Technology Institute, *Machine Tool Design Handbook*, Latest Edition, Kojo Press / CMTI Publications, 2024
5.	Bhattacharya, *Theory of Metal Cutting and Machine Tools*, 2nd Edition, Central Book Publishers, Second Edition, 2009.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Explain the principles, kinematics, and functional requirements of machine tools and their design considerations.
CO2	Design and analyze machine tool structural elements such as beds, columns, guideways, and spindles for strength and rigidity.
CO3	Select and design suitable machine tool drive systems and power transmission components including gears, bearings, and feed mechanisms.
CO4	Analyze machine tool vibrations, chatter, and thermal effects to improve machining accuracy and dynamic performance.
CO5	Apply modern CAD/CAE tools, CNC concepts, and optimization techniques for advanced machine tool design and development.

Course Code	:	ME716
Course Title	:	**Theory of Plasticity**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand elastic and plastic deformation mechanisms in metals
CLO2	To formulate constitutive equations for plastic behavior of materials
CLO3	To understand various yield criteria of materials
CLO4	To derive stress–strain relations in plastic deformation
CLO5	To understand finite plastic deformation

Course Content

Fundamentals: Elastic and plastic behavior of metals – mechanisms, dislocation and slip systems. Stress and strain tensors, deviatoric and hydrostatic stress, Principal stresses and invariants, Tensor calculus fundamentals. **Uniaxial plasticity:** True stress–true strain relation, Plastic strain, Experimental observations, Ideal plasticity, Bauschinger effect.

Yield Criteria: Pressure-Independent Materials - Tresca, Von mises Failure Criterion, Pressure-Dependent Materials- Mohr Columb, Rankine, and Drucker-Prager, Failure criteria for anisotropic materials, Comparison of yield theories.

Plasticity: Associative flow rule, Plastic potential, Levy–Mises equations, Prandtl–Reuss equations, Isotropic and Kinematic hardening, Combined hardening, consistency conditions, Kuhn-Tucker conditions, 3-D tangent elasto-plastic operator, tensorial projectors in matrix and vector form, return mapping algorithm, Nonlinear hardening rule.

Rate Dependent Behavior: viscoelasticity, classical viscoplasticity, Perzyna model, Creep models, geometrical nonlinearity, multiplicative decomposition, large deformation, thermomechanical behavior.

Finite Deformation: Multiplicative decomposition, intermediate configuration, Anisotropic plasticity, stress measures, flow rule and hardening rule

References

1.	Shabana, Ahmed A. *Computational continuum mechanics*. John Wiley & Sons, Third Edition, 2018.
2.	Simo, Juan C., and Thomas JR Hughes, *Computational inelasticity*. Vol. 7., Springer Science & Business Media, 2013.
3.	EA de Souza Neto, D Peric, DRJ Owen, *Computational methods for Plasticity*, John Wiley & Sons, 2008.
4.	Gerhard A. Holzapfel, *Nonlinear solid mechanics: A Continuum approach for Engineering*, Wiley, First Edition, 2000
5.	Ronaldo I. Borja, *Plasticity: Modeling & Computation,* Springer-Verlag Berlin and Heidelberg GmbH & Co, 2013.

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To understand the fundamental concepts of elastic and plastic deformation, including yielding, strain hardening, and permanent deformation mechanisms in engineering materials.
CO2	To apply tensor-based stress and strain analysis to plastic deformation problems and evaluate stress invariants, principal stresses, and deviatoric stresses.
CO3	To use classical yield criteria to predict yielding under multiaxial loading conditions.
CO4	To formulate and apply plastic flow rules, constitutive relations, and hardening laws for elastic–plastic materials.
CO5	To develop continuum mechanics formulations for finite plastic deformation using deformation gradient

Course Code	:	ME717
Course Title	:	**Continuum Mechanics**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce indicial and summation conventions for basic vectorial and tensorial operations
CLO2	To introduce tensorial calculus for understanding continuum behavior of matters in cartesian & curvilinear coordinates.
CLO3	To familiarize the kinematics of continuum body undergoes large deformation
CLO4	To familiarize different configurational dependent stress measures
CLO5	To understand the fundamental balance principles of continuum object

Course Content

Tensor - Introduction: Scalar, Vector, Second order Tensors, Indicial notation and summation convention, Dot, cross and dyadic products, Linear Transformation, Spherical & deviatoric projectors, Coordinate Transformation.

Tensor - Calculus: Eigen values and eigen vectors, Transformation of Tensors, Tensor valued functions, gradient operators and Integral theorems, fundamental metric tensor, Covariant & Contravariant.

Kinematics: Reference and deformed configurations, motion – velocity and acceleration in material & spatial representation, Deformation and displacement gradients, material and spatial stains measures, Line, area, and volume mappings, Nanson's formula, Polar decomposition - Rotation & stretch tensors, rate of deformation.

Kinetics: Concept of stress, Cauchy's stress theorem, first and second Piola- Kirchoff's & Cauchy's stress tensors, Normal and shear stress, Extremal stress values, stress states, **Objectivity** - tensor fields, rates, invariance.

Balance Principles: Mass conservation, Reynold's transport theorem, Momentum and energy balances in references and current configuration, Weak and strong forms of balance equation, Continuum thermodynamics.

Constitutive Relations: Isotropic hyperelastic materials – Compressible and Incompressible materials, strain-energy functions, elasticity tensors, transversely isotropic materials, constitutive models with internal variables, viscoelasticity.

References

1.	Gerhard A. Holzapfel, *Nonlinear solid mechanics: A Continuum approach for Engineering*, Wiley, 2000.
2.	W Michael Lai, David H. Rubin, Erhard Krempl, David Rubin, *Introduction to Continuum Mechanics*, Butterworth-Heinemann; 4th edition, 2009.
3.	J.N. Reddy, *An Introduction to Continuum Mechanics*, Cambridge University Press; 2nd edition, 2013.

4.	George E. Mase, *Schaum's Outline of Continuum Mechanics*, McGraw Hill; First edition, 2020.
5.	John W. Rudnicki, *Fundamentals of Continuum Mechanics*, Wiley, First Edition, 2014.
6.	A.J.M. Spencer, *Continuum Mechanics*, Dover Publications Inc., First Edition, 2004.

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To apply indicial notation and Einstein's summation convention on tensorial operations.
CO2	To represent physical parameters in tensorial notations and perform tensor calculus.
CO3	To understand the unified theory of continuum body such as fluids and solids undergoing deformation.
CO4	To differentiate stress and strain measures on a material and spatial point.
CO5	To represent linear momentum balance in material and spatial configuration

Course Code	:	ME718
Course Title	:	**Smart Materials and Structures**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the interdisciplinary material properties for sensors and actuators applications.
CLO2	To familiarize the working principles of various sensors for different applications.
CLO3	To demonstrate the role of actuators and actuator materials.
CLO4	To introduce the basic concepts of piezoelectric energy harvesting.
CLO5	To discuss the various measurements and signal processing techniques for structural dynamic applications.

Course Content

Introduction to Smart Materials, Structures - Smart materials (Physical Properties) Piezoelectric Materials, Magnetorheological Fluids, Electrorheological Fluids, Shape Memory Alloy Materials.

Smart Sensors and Technologies - Accelerometers - Force Sensors- Load Cells, Torque Sensors, Pressure Sensors, Microphones, Impact Hammers- MEMS Sensors – Fiber Optic Sensors.

Smart Actuator and its Techniques – Role of Actuators and Actuator materials – Piezoelectric and– Magneto-structural Materials – Shape Memory Alloys – Electro rheological fluids – Electromagnetic actuation.

Introduction to Piezoelectric Energy harvesting - Physics and characteristics of piezoelectric effect, materials and mathematical description of piezoelectricity, Piezoelectric parameters and modelling - Piezoelectric energy harvesting applications.

Measurement and Signal Processing Techniques – Static and Dynamic Measurement Methods- Signal conditioning devices; Structural dynamics and Identification techniques; Passive, Semi -active and Active control strategies.

References

1.	Srinivasan, A. V. and Michael Mc Farland, D., *Smart Structures: Analysis and Design*, Cambridge University Press, 2009.
2.	Gandhi, M. V. and Thompson B.S., *Smart Materials and Structures,* Chapman and Hall, London, 1992.
3.	Michelle Addington and Daniel L. Schodek, *Smart Materials and Technologies: For the Architecture and Design Professions*, Routledge 2005.
4.	Brain Culshaw, *Smart Structure and Materials*, Artech House – Borton. London,2004.
5.	Donald J. Leo., *Engineering Analysis of Smart Material Systems*, Wiley, 2007.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Make use of various smart materials properties for sensors and actuators applications.
CO2	Understand the working of sensors for various applications.
CO3	Identify the suitable actuators for various dynamic applications.
CO4	Model the piezoelectric effect for energy harvesting.
CO5	Demonstrate the measurement and signal processing techniques for structural dynamics testing.

Course Code	:	ME719
Course Title	:	**Advanced Robotics**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize students with different kinds of robots and their applications in present day word
CLO2	To make students derive and solve the kinematic and dynamic equations of motion of manipulators
CLO3	To make students learn and comprehend the concepts of Jacobian and manipulability
CLO4	To make students learn and implement linear and nonlinear control of robot manipulators
CLO5	To make students learn about the basics of robot sensing, vision and autonomy

Course Content

Definition and classification of robots and manipulators: Introduction, history and types of robots, need and application, overview of the functioning of a robot

Robot arm kinematics: Joint types, degrees of freedom, homogeneous transformation, Denavit-Hartenberg (DH) representation, direct and inverse kinematics

Robot arm dynamics: Lagrange-Euler formulation, Newton-Euler formulation, velocity propagation along links, manipulator Jacobian and singularities, manipulator trajectory planning

Control of robot manipulators: Position control of second order systems, control law partitioning, Lyapunov stability analysis, force control of manipulators

Sensing and vision: Range sensing, proximity sensing, touch sensors, force and torque sensors, image acquisition, image representation, image processing

Introduction to autonomous robots: Perception, localization, mapping, navigation

References

1.	Fu K.S., Gonzalez R.C. and Lee C.S.G., *Robotics: Control, Sensing, Vision and Intelligence*, McGraw Hill Education (India) Private Limited, 2017
2.	Craig J.J., *Introduction to Robotics – Mechanics and Control*, Pearson Education, 2017
3.	Mittal R.K. and Nagrath I.J., *Robotics and Control*, McGraw Hill Education (India) Private Limited, 2017
4.	Saha. S.K., *Introduction to Robotics*, McGraw Hill Education (India) Private Limited, 2014
5.	Ghosal A., *Robotics: Fundamental Concepts and Analysis*, Oxford UniversityPress, 2006

6.	Lynch K.M. and Park F.C., *Modern Robotics: Mechanics, Planning and Control*, Cambridge University Press, 2017
7.	Siegwart, R., Nourbakhsh, I. R., & Scaramuzza, D., Introduction to Autonomous Mobile Robots, MIT press, Second Edition, 2011

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To state or give a presentation on the state-of-the-art of robotics technology, applications and need for robots
CO2	To derive and solve the dynamic equations of motion of a manipulator.
CO3	To identify the singular configuration of manipulators
CO4	To apply the control laws for trajectory tracking of the robots
CO5	To state and write briefly about bringing autonomy in robotic systems

Course Code	:	ME720
Course Title	:	**Advanced Mechanisms Design**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To make students learn the various types of mechanisms and the kinematic fundamentals
CLO2	To make students synthesize mechanisms and linkages, both graphically and analytically
CLO3	To make students learn and comprehend the concepts of cognates and coupler curves
CLO4	To make students analyse the synthesized mechanisms
CLO5	To familiarize students with spatial mechanisms

Course Content

Kinematic Foundations: Review of kinematics fundamentals, links, pairs, and kinematic chains, planar mobility criterion and Gruebler's criterion, inversions, Grashof criterion, and kinematic equivalence

Graphical Linkage Synthesis: Classification of linkage synthesis; motion generation (2-position, 3-position), driver dyad and quick-return synthesis, path generation with specified fixed pivots, function generation (including relative poles method), structural error and Chebyshev spacing

Analytical Linkage Synthesis: Vector loop closure and analytical synthesis (Freudenstein's and Bloch's methods), four-bar position analysis and standard (dyad) form synthesis, dyad synthesis for motion, path, and function generation, multi-loop linkages and four-position motion generation

Coupler Curves and Mechanism Geometry: Coupler curves and their properties, fixed and moving centrodes, symmetrical coupler curves, Roberts–Chebyshev theorem and cognates

Kinematic Analysis (Velocity and Acceleration): Velocity polygons and instantaneous centres, auxiliary point method for velocity analysis, analytical velocity and acceleration analysis, auxiliary point method for acceleration analysis

Force Analysis, Balancing, and Spatial Mechanisms: Force analysis of mechanisms and mechanical advantage, balancing using counterweights and springs, introduction to spatial mechanisms and their kinematics

References

1.	Sandor, G. N., and Erdman, A. G., *Advanced Mechanism Design: Analysis and Synthesis*, Vol. II, Prentice-Hall, 1984

2.	Uicker Jr, J. J., Pennock, G. R., and Shigley, J. E., *Theory of Machines and Mechanisms*, Oxford University Press, 2017
3.	Hartenberg, R., and Danavit, J., *Kinematic Synthesis of Linkages*, McGraw-Hill: New York, 1964
4.	Mallik, A.K., and Ghosh, A., *Theory of Mechanisms and Machines*, Affiliated Esat-West Press Private Limited, 2015
5.	Norton, R. L., *Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines*, McGraw-Hill Education, 2019

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To perceive the importance of motion transformation involved in various mechanisms and able to make classifications
CO2	Gain the knowledge of synthesis methods and use software for mechanism animation
CO3	To precisely perform position analysis of linkages in mechanisms
CO4	To quantify the velocity and acceleration at required regions in a mechanism
CO5	To synthesize their own mechanisms

Course Code	:	ME721
Course Title	:	**Digital Manufacturing & Industry 5.0**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To provide a comprehensive understanding of the transition from traditional manufacturing to Industry 4.0 and onwards to the human-centric Industry 5.0.
CLO2	To impart knowledge on key enablers like Industrial IoT, Digital Twinning, etc.
CLO3	To discuss the role of AI in digital manufacturing
CLO4	To explain the principal and process involved in development of parts by additive manufacturing
CLO5	To understand the application of reverse engineering / discuss on techniques for processing of Geometric models for digital manufacturing

<u>Course Content</u>

Definition of digital manufacturing, Historical perspective on industrial production and outlook. Evolution of Industrial Revolutions: Transition from Industry 1.0 to 4.0 and 4.0 to 5.0. Industry 5.0 - Human Machine Interface, resilience, and sustainability.

Digital Twin & Simulation: Virtual modeling, simulation, and validation of production systems. Industrial Internet of Things (IIoT): Sensor integration, data acquisition, and cloud/edge computing.

Artificial Intelligence (AI) and Big Data: Predictive maintenance, AI-driven process optimization.

Additive Manufacturing (3D Printing) for Digital Transformation: Rapid prototyping and additive production methods. Introduction to 4D Technology.

Component modelling, Machine and tool selection, Defining process and parameters, Tool path generation, Simulation, Post processing. Reverse engineering process – Need, Hardware and Software – Geometric Model Development.

References

1.	Kim Phuc Tran, Zhenglei He, *Computational Techniques for Smart Manufacturing in Industry 5.0 Methods and Applications*, CRC Press, 2025.
2.	Zude Zhou Shane (Shengquan) Xie Dejun Chen, *Fundamentals of Digital Manufacturing Science*, Springer Series in Advanced Manufacturing, 2012 (Unit-I).
3.	*ASM Handbook, Additive Manufacturing Design and Applications*, 2023
4.	Vinesh Raja and Kiran J Fernandes, *Reverse Engineering- An Industrial Perspective*, Springer-Verlag, 2008.
5.	Ibrahim Zeid and Sivasubramanian R, *CAD/CAM - Theory and Practice*, Tata McGraw Hill Education, 2009.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Explain the principles, components, and design methodologies of digital manufacturing and smart factories.
CO2	Develop and implement digital twins and simulation models to optimize manufacturing processes and predict failures.
CO3	Integrate IoT sensors, AI, and data analytics for improving productivity and quality control in smart industries.
CO4	Understand the various processes used in additive manufacturing for a range of materials
CO5	Acquire the knowledge on hardware and software used in reverse engineering and Computer Aided Manufacturing (CAM)

Course Code	:	ME722
Course Title	:	**MEMS: Design, Fabrication and Characterization**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the fundamentals, evolution and applications of MEMS and microsystem technology
CLO2	Apply scaling laws and mechanical/electrical principles for MEMS device design.
CLO3	Learn and analyze MEMS fabrication processes such as lithography, deposition and etching.
CLO4	Design and evaluate MEMS sensors and actuators for real-time engineering applications.
CLO5	Characterize and validate MEMS devices using testing methods, packaging techniques and reliability analysis.

Course Content

Introduction to MEMS, NEMS and Microsystems: Overview, evolution and classification of MEMS/NEMS: micro & nano sensors, actuators and microfluidic devices. Comparison of MEMS/NEMS with IC technology, advantages, limitations and industrial applications. Materials for MEMS/NEMS, design cycle and case studies of accelerometer, pressure sensor and gyroscope.

MEMS/NEMS Design Principles and Modeling: Scaling laws, nano-scale effects, mechanical properties, stress, strain and deflection in micro/nano structures. Resonance, damping, quality factor, electrostatic and thermal actuation principles. Modeling of micro/nano beams and cantilevers, lumped models and FEM simulation using COMSOL/ANSYS/Coventor.

MEMS/NEMS Fabrication Technologies: Cleanroom practices, wafer preparation, photolithography, nanolithography and thin film deposition techniques. Oxidation, diffusion, etching, bulk/surface micromachining and SOI-based fabrication methods. LIGA, nano fabrication, micro molding and complete MEMS/NEMS process flow design.

MEMS/NEMS Sensors and Actuators: Capacitive, piezoelectric, piezoresistive, thermal, chemical and biosensors for MEMS/NEMS applications. Electrostatic, thermal, piezoelectric and magnetic actuators with micro/nano pumps and valves. RF MEMS/NEMS switches, nano resonators and smart sensing applications.

Characterization techniques: profilometry, SEM, AFM, nanoindentation, electrical and mechanical testing. Micro/nano packaging methods including wafer bonding, wire bonding and flip-chip packaging. Reliability issues such as fatigue, creep, stiction and wear with industrial case studies on MEMS/NEMS.

References

1.	Marc J. Madou, *Fundamentals of Microfabrication and Nanotechnology,* 3rd Edition, CRC Press, 2018**.**

2.	Tai-Ran Hsu, *MEMS and Microsystems: Design, Manufacture, and Nanoscale Engineering,* 4th Edition, Wiley, 2020.
3.	Stephen D. Senturia, *Microsystem Design*, Springer, 2001
4.	Nadim Maluf & Kirt Williams, *An Introduction to Microelectromechanical Systems Engineering*, 2nd Edition, Artech House, 2004.
5.	G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat & V. K. Aatre, *Micro and Smart Systems,* Wiley, 2012.
6.	M. Gad-El-Hak, *The MEMS Handbook*, CRC Press, Second Edition, 2020.
7.	Chang Liu, *Foundations of MEMS,* Pearson, 2011

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To introduce fundamentals of MEMS and microsystem technologies with engineering design approach.
CO2	To understand MEMS design principles including scaling laws, microstructures, and device modeling.
CO3	To explain MEMS fabrication processes such as lithography, etching, deposition and micromachining.
CO4	To analyze MEMS sensors and actuators for various engineering applications.
CO5	To study MEMS characterization techniques, packaging methods and reliability testing.

Course Code	:	ME723
Course Title	:	**Tribology in Design**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize students with tribological concepts and phenomena
CLO2	To make students learn and analyze different types of friction and measurement techniques
CLO3	To make students learn different wear models and controlling techniques
CLO4	To make students learn about lubrication and coating to reduce wear
CLO5	To make students learn the basics of surface topography measurements

Course Content

Introduction: Overview of the course, history and basic concept of friction, wear and lubrication. Physical and chemical characterization of surfaces-**Surface roughness**- tools for roughness characterization- Industrial norms in roughness quantification/characterization-surface finish symbols- Characterization of surface morphology – The Scanning Electron Microscope- backscattered and secondary imaging- X-ray dispersive analysis. X-ray photo-electron spectroscopy and chemical characterization of surface films.

Friction: Friction in contacting rough surfaces, sliding and rolling friction, various laws and theory of friction. Stick-slip friction behavior, frictional heating and temperature rise. Friction measurement techniques

Wear: Wear –Types of wear: adhesive, abrasive, corrosive, fretting wear- quantification of wear- wear of metals and non-metals, debris analysis. Pin-on-disk machine and the Four Ball Tester. Friction and wear in IC engines, Bearings, Gears, cams etc.

Lubricants: Types of lubricants, Objectives of lubricants, Physical properties of lubricants, Selection of lubricants. Friction-coefficient of friction- Stribeck curve-Lubrication regimes- Film thickness parameter- Fundamentals of hydrodynamic lubrication - Hydrodynamic pressure profile-Visualization and Measurement of film thickness in well-lubricated contacts. Boundary lubrication, plowing, and adhesion components-Pin-on-plate arrangement to measure friction.

Measurements: electron microscope and friction and wear measurements; laser method. Sliding friction and wear abrasion test, rolling contact and fatigue test, solid particle and erosion test, Use of transducers and instruments in Tribology

References

1.	Halling J., *Principles of Tribology*, Palgrave Macmillan, 1978
2.	Williams J.A., *Engineering Tribology*, Oxford University Press, 1994
3.	Hutchings I., and Shipway P., *Tribology: Friction and Wear of Engineering Materials*, Butterworth-Heinemann Ltd., Second Edition 2017
4.	Stachowiak G. W., and Batchelor A. W., *Engineering Tribology*, Butterworth Heinemann Ltd., 2016.
5.	Ludema K.C., and Ajayi O.O., *Friction, Wear, Lubrication: A Textbook in Tribology*, CRC Press, Second Edition, 2018

6.	A. K. Chitale, R. C. Gupta, *Product Design and Development*, PHI Learning Pvt. Ltd, 5th Edition, 2011.

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To be aware of state-of-the-art of tribology, applications and industrial significance
CO2	To state different types of friction, stick-slip phenomena and techniques of measuring friction
CO3	To analyse and study the different wear models and methods of controlling wear
CO4	To analyse and apply lubrication in tribology to reduce friction
CO5	To measure and quantify surface topology measurements

Course Code	:	ME724
Course Title	:	**Reverse Engineering**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize with Reverse Engineering methodologies and methods to understand product functionality.
CLO2	To analyze part durability, fatigue, failure modes, and material identification.
CLO3	To impart knowledge on capturing the data and processing the data.
CLO4	To understand the 3D scanning hardware & software operations and procedure for generating the 3D model
CLO5	To apply the Reverse engineering concepts in various industries and discuss the legal considerations, intellectual property rights, and ethical implications of reverse engineering

Course Content

Introduction: Purpose of reverse engineering - Generic process – Phases – Computer Aided Reverse Engineering -Surface and Solid Model Reconstruction – Dimensional Measurement – Prototyping.

Material analysis and Manufacturing Process Identification: Alloy Structure Equivalency – Phase Formation and Identification – Mechanical Strength -Hardness – Analysis of Failure modes – Fatigue, Creep and Stress rupture Environmentally Induced Failure Material Specification – Composition Determination – Microstructure Analysis – Verification of Manufacturing Process based on part characteristics.

Data Acquisition and Processing: Capturing raw data, noise reduction, filtering, and data splicing to remove artifacts. Statistical analysis, reliability modeling, data report generation, and system performance evaluation.

Scanning and Modelling: Introduction, working principle and operations of 3D scanners: Laser, White Light, Blue Light -Applications- Software for scanning and modelling: Types- Applications- Preparation techniques for Scanning objects- Scanning and Measuring strategies – Calibration and Inspection - Case studies.

Industrial Applications: Reverse Engineering in Aerospace, automotive, and medical device industries. Case studies and Solving Industrial projects in Reverse Engineering. Legal Aspects of Reverse Engineering: Copyright law – Patents – Intellectual property (IP) – Third Party Materials.

References

1.	Kathryn, A. Ingle, *Reverse Engineering*, McGraw-Hill, 1994
2.	Robert W. Messler, Jr. *Reverse Engineering: Mechanisms, Structures, Systems And Materials*, McGraw-Hill, First Edition, 2013
3.	Wego Wang, *Reverse Engineering Technology of Reinvention*, CRC Press, 2011
4.	Kevin Otto and Kristin Wood, *Product Design: Techniques in Reverse Engineering and New Product Development*, Prentice Hall, 2001

5.	Vinesh Raj and Kiran Fernandes, *Reverse Engineering: An Industrial Perspective*, Springer-Verlag London Limited 2008.
6.	Peter Aiken, *Data Reverse Engineering: Untying the Legacy Knot*, McGraw-Hill, 1994

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Describe phases of reverse engineering and apply them to create design documents from existing parts.
CO2	Evaluate material characteristics, part failure (fatigue, creep), and verify product processes.
CO3	Apply the concept and principles of data processing, part performance and system compatibility
CO4	Acquire the knowledge of 3D scanning and modelling of Reverse Engineered parts and components
CO5	Identify and comply with legal aspects related to intellectual property

Course Code	:	ME725
Course Title	:	**Drone Technology**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart the knowledge of Unmanned Aerial Vehicles (UAVs) and drones.
CLO2	To understand the flight and aerodynamics of drones.
CLO3	To familiarize with the propulsion systems utilized in drones
CLO4	To understand the mechanical design aspects of drones, control system and its stability
CLO5	To familiarize with the current technologies and regulatory environment in drone development and operation.

Course Content

Introduction: Drone Evolution – Basic Drone Components and Architecture – Classification - Airframe Structures and materials, Unmanned Aerial Vehicle (UAV) - Types of UAVs: fixed-wing, rotary-wing, hybrid - Classification based on size, range, and applications

Fundamentals of Flight and Aerodynamics - Basic flight physics - Lift, drag, thrust, and weight - Airfoil design - basics and rotor blade aerodynamics

Propulsion Systems - Electric vs. fuel-based propulsion - Sizing of motors and propellers - Efficiency considerations

Mechanical Design of Drone Frames - Structural design and material selection - Load distribution, stress and strain analysis - Vibration and damping in drone structures. Stability and Control Basics - Principles of stability in flight - PID control basics - Role of gyroscopes and accelerometers

Embedded Systems and Sensors in Drones - Flight Controllers and Programming Basics - Regulations and Safety – Application and Recent trends in Drone Technology – Case studies.

References

1.	David McGriffy, *Make: Drones - Teach an Arduino to Fly*, O'Reilly, First Edition, 2016
2.	Reg Austin, *Unmanned Aircraft Systems UAV design, development and deployment*, Wiley, 2010
3.	Robert C. Nelson, *Flight Stability and Automatic Control*, McGraw-Hill, Inc, 1998.
4.	Kimon P. Valavanis, *Advances in Unmanned Aerial Vehicles: State of the Art and the Road to Autonomy*, Springer, 2007
5.	Dr Raja Mogili Amirisetty, *THE DRONE LAW IN INDIA*, Gogia Law Agenency, 2019
6.	Paul G. Fahlstrom, Thomas J. Gleason, and Mohammed H. Sadraey, *Introduction to UAV Systems*, John Wiley & Sons, Inc. , 5th edition, 2022

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Explain the architecture and classifications of drones and UAVs
CO2	Design and analyse the basic drone frames and aerodynamics with attention to mechanical performance and payload.
CO3	Understand the propulsion systems used in drones
CO4	Understand basic control principles and flight stability.
CO5	Explore real-world applications and challenges in drone deployment.

2. Automotive Engineering Focus

Course Code	:	ME726
Course Title	:	**Automotive Chassis & Body Engineering**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the design of chassis layout based on vehicle usage.
CLO2	To study the body construction types for cars, buses, and commercial vehicles.
CLO3	To impart knowledge on the effects of structural forces, aerodynamic forces, and moments on the vehicle frame and body.
CLO4	To understand the ergonomic requirements for vehicle body design.
CLO5	To familiarize the modern vehicle safety features to meet the current requirements.

Course Content

Automotive Chassis: Types, Classifications based on layout, engine fitment location, drive, and fabrication. Automotive Frames - Material Selection and Constructional Details, Different Loads acting on Frame, Testing of Automotive Frames.

Passenger Car Body: Classification of vehicles based on body types. Integral body construction details: Requirements of body, Loads acting on the vehicle body, Types of materials used in body construction. Selection of body member sections, Body sub frame and underfloor structure, car roof, front, and rear end structure. Vehicle Structure Analysis by Simple Structural Surface (SSS) Method: Sedan and simple van.

Bus and Commercial Vehicle body: Classifications based on usage, weight, and body type, designed to move people, goods, or perform specialized tasks. Types of metal sections used in construction and regulations. Construction of conventional and integral type buses and comparison. Construction of Tanker, Tipper, Tractor-Trailer, Cargo Truck, and Pickup bodies.

Vehicle Aerodynamics: External and Internal flow problems, Resistance to vehicle motion, Drag and lift forces. Methods for evaluating Aerodynamics of Cars, Various body optimization techniques for minimum drag and lift.

Ergonomic and Safety: Occupant packaging, Anthropometric measurements. Interior design for comfort, ease of use, and aesthetics: seats, dashboard instruments, pedal controls, and electronic displays. Driver seat design for car, bus, and commercial vehicle body. Safety features and requirements for occupant protection and pedestrian safety, Crumple zones, Safety Regulations. Introduction to Crash test, chassis and body alignment test.

References

1.	Reimpell, J., Stoll, H. and Betzler, J., *The Automotive Chassis: Engineering Principles.* Elsevier. 2001.
2.	Halderman, J.D. and Mitchell, C.D., *Automotive Chassis Systems*. Prentice Hall. 2010.
3.	Fenton, J., *Handbook of Automotive Body & Systems Design*. Wiley. 1998.
4.	Heisler, H., *Advanced Vehicle Technology*. Elsevier. 2002.

5.	Dae Crolla, A., *Automotive Engineering Powertrain, Chassis System and Vehicle Body*. Butterworth-Heinemann. 2009
6.	Bhise, V.D., *Ergonomics in the Automotive Design Process: Advanced Topics, Measurements, Modeling and Research*. CRC press. 2024.
7.	Gonter, M. and Seiffert, U.W., *Integrated Automotive Safety Handbook*. SAE International, 2013.

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To suggest a suitable chassis layout based on vehicle usage.
CO2	To choose appropriate body construction types for cars, buses, and commercial vehicles.
CO3	To analyze the effects of structural forces, aerodynamic forces, and moments on the vehicle frame and body.
CO4	To identify the ergonomic requirements for vehicle body design.
CO5	To select the essential safety features for cars, buses, and commercial vehicles.

Course Code	:	ME727
Course Title	:	**Vehicle Dynamics & Control**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand vehicle load distribution while acceleration and braking.
CLO2	To impart knowledge on the aerodynamics of the vehicle body.
CLO3	To study the mechanical properties of tires and their rolling resistance.
CLO4	To be acquainted with the lateral dynamics of vehicle.
CLO5	To be familiarized with the design of automotive suspension systems.

Course Content

Introduction to Vehicle Dynamics. Longitudinal Dynamics: Vehicle load distribution – Acceleration and Braking, Brake force distribution, Braking efficiency and braking distance. Passenger car and Tractor-semi trailer models. Introduction to longitudinal control.

Vehicle Aerodynamics: Mechanics of Air Flow Around a Vehicle, Pressure Distribution on a Vehicle, Resistance to vehicle motion, Drag and lift forces. Methods for evaluating Aerodynamics of Cars, Various body optimization techniques for minimum drag and lift.

Tire Mechanics: Mechanical properties of rubber – Slip, grip and rolling resistance, Tire construction and force development, contact patch and contact pressure distribution, Tire Brush Model, Lateral force generation – ply steer, conicity, and camber, Magic Formula Tire Model, Classification of Tire Models and Combined Slip.

Lateral dynamics: Bicycle Model, Stability and steering conditions, Understeer gradient, Steering control system. Handling response of a vehicle, Parameters affecting vehicle handling characteristics. Rollover prevention.

Vertical Dynamics: Full, half and quarter car suspension models. Design and analysis of passive, active and semi-active suspension systems.

References

1.	Gillespie, T., *Fundamentals of Vehicle Dynamics*. SAE International. 2021.
2.	Rajamani, R., *Vehicle Dynamics and Control*. Springer. 2012.
3.	Jazar, R.N., *Vehicle Dynamics: Theory and Application*. Springer Nature. 2025.
4.	Wong, J.Y., *Theory of Ground Vehicles*. John Wiley & Sons. 2022.
5.	Hucho, W.H., *Aerodynamics of Road Vehicles: From Fluid Mechanics to Vehicle Engineering.* Elsevier. 2013.
6.	Pacejka, H., *Tire and Vehicle Dynamics*. Elsevier. 2005.
7.	Karnopp, D., *Vehicle Stability*. New York: Marcel Dekker. 2004.

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To analyze road vehicles for their longitudinal dynamic response during acceleration and braking.
CO2	To study the effects of aerodynamic forces on the vehicle body.
CO3	To select tires with minimal rolling resistance and adequate contact pressure distribution based on vehicle usage.
CO4	To evaluate road vehicles for their lateral dynamic response while cornering.
CO5	To estimate and minimize road disturbances while moving on a rough patch of the road.

Course Code	**:**	ME728
Course Title	**:**	**Electric & Hybrid Vehicle Engineering**
Type of Course	**:**	Programme Elective (PE)
Prerequisites	**:**	NIL
Contact Hours	**:**	3
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the importance of electric and hybrid vehicles.
CLO2	To impart knowledge on constructions, functions, and technological features of electric and hybrid vehicles.
CLO3	To familiarize the configuration and control of various EV drive systems.
CLO4	To study different energy storage technologies used in EVs and HEVs.
CLO5	To understand the utilization of fuel cells and uses of alternative energy systems.

<u>Course Content</u>

Introduction to Electric and Hybrid Electric Vehicles: History, Social and Environmental Importance, Impact of modern drivetrains on energy supplies.

Conventional Drivetrains: Basics of vehicle performance, vehicle power source characterization, transmission characteristics. Electric and Hybrid Drivetrains: Basic concept of electric and hybrid traction, Introduction to various drivetrain topologies, Regenerative braking. Power flow control in EVs, HEVs, PHEVs, and FCEVs.

Electric Propulsion unit: Configuration and control of Brushed DC Motor drives, Brushless DC (BLDC) Motor drives, Permanent Magnet Synchronous Motor (PMSM) drives, Induction Motor (IM) drives, Switched Reluctance Motor (SRM) drives, Hybridization of different drive systems. Sizing the drive system: Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology.

Energy Storage: Battery based energy storage and its analysis, Maintenance and charging of batteries, Battery thermal management system (BTMS). Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices. Energy Management Strategies.

Case Studies: Design of a Battery Electric Vehicle (BEV), strong Design of a Hybrid Electric Vehicle (HEV).

References

1.	Ehsani, M., Gao, Y., Longo, S. and Ebrahimi, K., *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*. CRC press. 2018.
2.	Husain, I., *Electric and Hybrid Vehicles: Design Fundamentals*. CRC press. 2021.
3.	Mi, C. and Masrur, M.A., *Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives.* John Wiley & Sons. 2025.
4.	Denton, T., *Electric and Hybrid Vehicles*. Routledge. 2020.
5.	Larminie, J. and Lowry, J., *Electric Vehicle Technology Explained*. John Wiley & Sons. 2012.

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To realize the importance of electric and hybrid transportation systems.
CO2	To understand the basics of electric and hybrid vehicle components and configurations.
CO3	To understand the configuration and control of various EV drive systems.
CO4	To identify suitable energy storage technology for EVs and HEVs.
CO5	To possess knowledge about various alternative energy systems and fuel cells.

3. Aerospace Engineering Focus

Course Code	:	ME729
Course Title	:	**Advanced Flight Dynamics & Stability**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To develop a strong foundation in aircraft dynamic stability, including first- and second-order system behavior.
CLO2	To derive and analyze the 6-DOF equations of motion and develop linearized small-perturbation models for both longitudinal and lateral-directional dynamics.
CLO3	To evaluate aircraft stability by determining system roots, identifying dynamic modes (short period, phugoid, spiral, roll, Dutch roll).
CLO4	To design and analyze transfer functions and implement Stability Augmentation Systems (SAS) for improving aircraft dynamic response.
CLO5	To understand the role of inertial sensors (gyroscopes, accelerometers) and apply them in flight stability analysis.

Course Content

Introduction to dynamic stability - First and second order system - Solution of second order system using Laplace transform.

Physical interpretation of natural and damped frequencies damping ratio time to half and time to double, 6dof equations motion of aircraft.

Euler angles - Development of longitudinal small perturbed equations of motion - Dimensional derivatives - Roots, short period and long period mode.

Design of SAS for longitudinal mode - Transfer function and longitudinal mode shapes - Lateral directional perturbed equations of motion.

Dimensional derivatives lateral - Roots lateral - Spiral roll and dutch roll mode - Transfer function Lateral - Design of SAS for lateral - Mode shape - Inertial Sensors.

References

1.	Nelson, R.C., *Flight Stability and Automatic Control*, McGraw Hill Science Engineering, 1998.
2.	Etkin, B. & Reid, L., *Flight Stability and Automatic Control*, John Wiley & Sons Inc, 1995.
3.	Stevens, B.L. & Lewis, F.L., *Aircraft Control and Simulation*, Wiley-Blackwell, 2016.
4.	Cook, M.V., *Flight Dynamics Principles: A Linear Systems Approach to Aircraft Stability and Control (Aerospace Engineering)*, 2012.
5.	John H. Blakelock., *Automatic Control of Aircraft and Missiles*, John Wiley, 1991.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Explain and analyze the dynamic behavior of first- and second-order system.
CO2	Derive and formulate the 6-DOF equations of motion and obtain linearized small-perturbation models.
CO3	Analyze aircraft stability by determining system roots (eigenvalues), identify and interpret dynamic modes.
CO4	Develop transfer function models and design Stability Augmentation Systems (SAS).
CO5	Apply inertial sensor data (gyroscopes, accelerometers) and integrate measurement systems for flight stability analysis.

Course Code	:	ME730
Course Title	:	**Composite Materials for Aerospace**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the classification, characteristics, and advantages of composite materials used in aerospace applications.
CLO2	To familiarize students with various fabrication processes.
CLO3	To gain knowledge of various mechanical testing techniques.
CLO4	To enable students to analyze mechanical behavior and micromechanics of composites.
CLO5	To develop the ability to apply design principles of composites.

Course Content

Classification and characteristics of composite materials - Types of fiber and resin materials, functions and their properties – Application of composite materials for aerospace.

Fabrication processes - Wet/Hand Lay-Up – Spray Lay-Up – Autoclave Curing – Filament Winding – Pultrusion – Braiding -Vacuum Bagging - Resin Transfer Molding (RTM) - Centrifugal Casting.

Composite Testing - Quality Assessment and Physical Properties - Tensile and Compressive Testing - Shear and Flexural Testing.

Micromechanics-Mechanics of materials, Elasticity approaches-Mass and volume fraction of fibers and resins-Effect of voids, Effect of temperature and moisture.

Design Considerations in Composites - Orthotropic and Monoclinic Behaviour - Laminate Coefficients of Thermal and Hygral Expansions - Interlaminar Stresses - Free Edge Effects.

References

1.	R.M. Jones, Mechanics of Composite Materials, 2nd Edition, Taylor & Francis, 2018.
2.	AK Kaw. Mechanics of Composite Materials. 2nd Edition, CRC Press, New York, 2005.
3.	JM Hodgkinson, Mechanical Testing of Advanced Fibre Composites, Woodhead Publishing Limited, Cambridge, England, 2000.
4.	SS Pendhari, T Kant, YM Desai., Application of polymer composites in civil construction: A general review. Composite Structures, 2008.
5.	BD Agarwal, LJ Broutman, K Chandrashekhara., Analysis and Performance of Fibre Composites, 3rd Edition, John Wiley & Sons, Inc. New York, 2006.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Classify composite materials and explain the characteristics, properties, and functions.
CO2	Describe and compare various composite fabrication processes.
CO3	evaluate mechanical properties of composites through tensile, compressive, shear, and flexural testing.
CO4	Analyze composite behavior using micromechanics principles.
CO5	Apply design principles of composite materials.

Course Code	:	ME731
Course Title	:	**Computational Fluid Dynamics for Aerospace Applications**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To introduce numerical modeling and its role in the field of heat transfer and fluid flow.
CLO2	To understand the various discretization methods for simplifying the differential equations.
CLO3	To apply different numerical solution methods for the system of equations.
CLO4	To numerically solve steady and unsteady state diffusion and convection diffusion problems.
CLO5	To solve complex problems in the field of heat transfer and fluid dynamics by using high speed computers.

Course Content

Computational Fluid Dynamics for Aerospace: Introduction, advantages, and aerospace applications (aerodynamics and propulsion), Fundamental principles of conservation, Reynolds Transport Theorem, Conservation of mass, Conservation of linear momentum: Navier-Stokes equation, Conservation of energy including compressible flow equations, General scalar transport equation. Approximate Solutions of Differential Equations: Error minimization principles, Functional involving higher order derivatives, Essential and natural boundary conditions.

Discretization methods - Finite Element Method and Finite difference methods: Well posed boundary value problem, Possible types of boundary conditions, Conservativeness, Boundedness, Transportiveness, Finite volume method (FVM), Illustrative examples, Handling complex aerodynamic geometries. Discretization of 1-D unsteady state diffusion problems: implicit, fully explicit, and Crank-Nicholson scheme.

Important Consequences of Discretization of Time Dependent Diffusion Type Problems: Consistency, Stability, Convergence, Grid independent and time independent study, CFL condition for high-speed flows, Stability analysis of parabolic and hyperbolic equations. Finite Volume Discretization of 2-D unsteady State Diffusion type problems.

Solution of Systems of Linear Algebraic Equations: Criteria for unique solution, infinite number of solutions and no solution, Solution techniques for systems of linear algebraic equations: Elimination, Iteration and Gradient Search methods with examples. Norm of a vector, Norm of a matrix, some important properties of matrix norm, Error analysis of elimination methods.

Finite volume discretization of Convection-Diffusion Equations: Schemes. The concept of false diffusion, QUICK scheme, Introduction to shock-capturing. Discretization of Navier Stokes Equations: Discretization of the Momentum Equation, Staggered grid and Collocated grid, pressure-velocity coupling, Density-based versus pressure-based solvers, Chorin's projection method. The basic structure of a CFD code: Pre-processor, Solver and Postprocessor, User-defined subroutines.

References

1.	Tannehill, J.E., Anderson, D.A., and Pletcher, R.H., *Computational Fluid Mechanics and Heat Transfer*, 2nd ed., Taylor & Francis, 1997.
2.	Hoffmann, K.A. and Chiang, S.T., *Computational Fluid Dynamics for Engineers*, Engineering Education Systems, 2000.
3.	Anderson J.D., *Computational Fluid Dynamics – The basics with Applications*, Mc Graw-Hill, 1995.
4.	Versteeg, H.K. and Malalasekera, W., *An Introduction to Computational Fluid Dynamics – The finite volume method*, Longman Scientific & Technical, 1995.
5.	Patankar, S.V., *Numerical Heat Transfer & Fluid Flow*, Hemisphere, 1980.
6.	Date A.W., *Introduction to Computational Fluid Dynamics*, Cambridge University Press, 2005.
7.	Ferziger, J. H., Perić, M., & Street, R. L., *Computational methods for fluid dynamics*, Vol. 3, Berlin: springer, 2002.

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To express numerical modeling and its role in the field of fluid flow and heat transfer.
CO2	To estimate the various errors and approximations associated with numerical techniques.
CO3	To apply the various discretization methods and solution procedures to solve flow and heat transfer problems.
CO4	To perform stability analysis for different numerical schemes.
CO5	To evaluate the best method for a given thermo-fluids problem.

Course Code	:	ME732
Course Title	:	**Finite Element Analysis for Aerospace Applications**
Type of Course	:	Program Elective
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To impart the concept of shear deformation in solving BVP using FEM.
CLO2	To be familiarized with nonlinear structural mechanics problems.
CLO3	To study aerospace structures under dynamic and buckling loads using FEM.
CLO4	To be acquainted with thermal effects on structures, contact problems, and fluid-structure interaction.
CLO5	To explore non-conventional numerical techniques beyond FEM.

<u>Course Content</u>

Linear finite element formulations of shear deformable beam and plate elements, Shear locking. Application to composite, Functionally Graded Materials (FGMs), and sandwich structures.

Geometric and material nonlinearities: Nonlinear finite element formulation with application to beam and plate problems. Solution techniques: Newton-Raphson, displacement control, and arc-length control methods.

Solution of transient dynamic problems, explicit and implicit time integration techniques. Introduction to buckling problems.

Structural mechanics problems involving initial strains and thermal effects. Finite element formulation for contact problems and fluid-structure interaction (FSI).

Introduction to Smoothed Finite Element Method (S-FEM), Extended Finite Element Method (XFEM), Spectral Element Method (SEM), and Meshfree methods.

References

1.	Bathe, K.J., *Finite Element Procedures*. Prentice Hall, Pearson Education, Inc. 2006.
2.	Reddy, J.N., *An Introduction to Nonlinear Finite Element Analysis: With Applications to Heat transfer, Fluid Mechanics, and Solid Mechanics*. Oxford university press. 2015.
3.	Zienkiewicz, O.C. and Taylor, R.L., *The Finite Element Method for Solid and Structural Mechanics*. Elsevier. 2005.
4.	Sigrist, J.F., *Fluid-Structure Interaction: An Introduction to Finite Element Coupling*. John Wiley & Sons. 2015.
5.	Liu, G.R. and Trung, N., *Smoothed Finite Element Methods*. CRC press. 2016.
6.	Mohammadi, S., *Extended Finite Element Method: for Fracture Analysis of Structures*. John Wiley & Sons. 2008.
7.	Lee, U., *Spectral Element Method in Structural Dynamics*. John Wiley & Sons. 2009.
8.	Liu, G.R., *Meshfree Methods: Moving Beyond the Finite Element Method*. CRC press. 2009.

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To apply the concept of shear deformation in solving BVP using FEM.
CO2	To formulate and solve structural mechanics problems involving geometric and material nonlinearities.
CO3	To analyze aerospace structures under dynamic and buckling loads using FEM.
CO4	To handle thermal effects on structures, contact problems, and fluid-structure interaction numerically.
CO5	To possess knowledge about various non-conventional numerical techniques.

4. Cross-Cutting & Advanced Topics

Course Code	:	ME733
Course Title	:	**Multibody system Dynamics**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	4
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize students with the mathematical foundations and kinematics of rigid multibody systems
CLO2	To make students understand the kinetic and dynamic formulations of constrained multibody systems
CLO3	To make students learn numerical methods and computational algorithms for multibody dynamic analysis
CLO4	To make students model and simulate rigid and flexible multibody systems using modern software tools
CLO5	To make students analyse practical engineering systems involving multibody dynamics in robotics, vehicles, and machinery

Course Content

Mathematical foundations and kinematics: Vectors, tensors, reference frames, coordinate systems, orientation and parametrization, rotation matrices, angular velocity and acceleration, translational kinematics, spatial kinematics, screw theory, kinematics of serial chains, Jacobian and singularities, velocity and acceleration analysis of rigid multibody systems

Kinetics and analytical mechanics: Mass distribution and inertia properties, Newton–Euler formulation, variational principles, Lagrangian dynamics, Hamiltonian mechanics, extended Hamilton's principle, comparison of dynamic formulations for multibody systems

Multibody system formulation: Topology of multibody systems, generalized coordinates, kinematic constraints, joint modeling, constrained equations of motion, reduction methods, Maggi's equations, Kane's equations, contact and impact mechanics

Numerical methods and computational algorithms: Forward and inverse dynamics, numerical integration of ordinary differential equations, implicit integration schemes, differential-algebraic equation solvers, constraint stabilization, symplectic integration, computational efficiency and stability considerations

Flexible multibody dynamics: Classification of flexible multibody systems, elastodynamic formulation, finite displacement kinematics, strain measures, flexible joints, cable dynamics, beam, plate and shell formulations, finite element methods for multibody systems

Computer simulation and engineering applications: Modeling and simulation using MATLAB/Simscape Multibody, MSC ADAMS, and MuJoCo; solver comparison; applications to robotic manipulators, vehicles, offshore cranes, telescopic systems, and other engineering case studies

References

1.	Shabana, A. A., *Dynamics of Multibody Systems*, Cambridge University Press, 2020
2.	Shabana, A. A., *Computational Dynamics*, John Wiley & Sons, 2009.
3.	Featherstone, R., *Rigid Body Dynamics Algorithms*, Springer, 2008
4.	Bauchau, O. A., *Flexible Multibody Dynamics*, Springer, 2011
5.	Jazar, R. N., *Advanced Dynamics: Rigid Body, Multibody, and Aerospace Applications*. John Wiley & Sons, 2011
6.	Haug, E. J., *Computer-aided Kinematics and Dynamics of Mechanical Systems: Volume II: Modern Methods*, 2022
7.	Ginsberg, J. H., *Advanced Engineering Dynamics*, Cambridge University Press, 1998

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To formulate the kinematic relationships of rigid multibody systems using appropriate coordinate representations
CO2	To derive equations of motion of constrained multibody systems using Newton–Euler, Lagrangian, and other analytical methods
CO3	To implement numerical algorithms for solving multibody dynamic problems involving ordinary and differential-algebraic equations
CO4	To model and simulate rigid and flexible multibody systems using modern computational tools
CO5	To analyze and solve practical engineering problems involving multibody systems in robotics, vehicles, and mechanical systems

Course Code	:	ME734
Course Title	:	**Optimization Techniques in Mechanical Engineering**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the need and origin of the optimization methods.
CLO2	Get a broader picture of the various applications of optimization methods used in engineering.
CLO3	Get a broader picture of the various applications of optimization methods used in engineering.
CLO4	Formulate optimization problems as mathematical programming problems.
CLO5	Briefly learn about classical and advanced techniques in optimizations

Course Content

Introduction Historical Development; Engineering applications of Optimization; Modeling, Objective function; Constraints and Constraint surface; Formulation of design problems as mathematical programming problems, Classification of optimization problems, Optimization techniques – classical and advanced techniques

Optimization using Calculus Stationary points; Functions of single and two variables; Global Optimum, Convexity and concavity of functions of one and two variables,

Optimization of functions of one variable and multiple variables; Gradient vectors; Optimization of functions of multiple variables subject to equality constraints; Lagrangian function, Optimization of functions of multiple variables subject to equality constraints; Hessian matrix formulation; Eigen values, Kuhn-Tucker Conditions; Examples

Linear Programming Standard form of linear programming (LP) problem; LP Models; Elementary operations, Graphical method for two variable optimization problem; simplex method, Dual Simplex method, Primal-dual relations; Sensitivity or post optimality analysis,

Non-conventional algorithms Introduction and Principles of Evolutionary Computation (EC), Binary-Coded Genetic (BCGA), Differential Evolution (DE), Particle Swarm Optimization (PSO), Piecewise linear approximation of a nonlinear function, Multi objective optimization – Weighted and constrained methods; Multi level optimization, Direct and indirect search methods, Evolutionary algorithms for optimization and search, Application in Mechanical Engineering

References

1.	S.S. Rao, *Engineering Optimization: Theory and Practice*, New Age International P)Ltd., New Delhi, 2000.
2.	G. Hadley, *Linear programming*, Narosa Publishing House, New Delhi, 1990.
3.	H.A. Taha, *Operations Research: An Introduction*, 5th Edition, Macmillan, New York, 1992.
4.	K. Deb, *Optimization for Engineering Design Algorithms and Examples*, Prentice-Hall of India Pvt. Ltd., New Delhi, 1995.

5.	K. Srinivasa Raju and D. Nagesh Kumar, *Multicriterion Analysis in Engineering and Management*, PHI Learning Pvt. Ltd., New Delhi, India, 2010.

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Enumerate the necessity of optimization in engineering design
CO2	Identify the various optimization techniques pertaining to design-oriented problems.
CO3	Solve problems with single and multi – variable.
CO4	Solve the real-world problem with linear programming
CO5	Apply advanced algorithms for optimization of typical problems requiring their application.

Course Code	:	ME735
Course Title	:	**Mechatronic System Design**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize students with the fundamentals of mechatronics and integrated system design
CLO2	To make students understand the selection and integration of sensors, actuators, and control systems
CLO3	To make students learn modeling and analysis of mechatronic systems
CLO4	To make students design and implement control strategies for mechatronic applications
CLO5	To make students develop complete mechatronic systems for real-world engineering applications

Course Content

Introduction to mechatronic systems: Definition, evolution and scope of mechatronics, elements of a mechatronic system, interdisciplinary nature, system-level design approach, applications in modern engineering

Sensors and transducers: Types of sensors (displacement, velocity, force, temperature, pressure), working principles, signal conditioning, data acquisition systems, sensor selection and calibration

Actuators and drive systems: Electrical, hydraulic and pneumatic actuators, stepper motors, servo motors, DC and AC drives, characteristics and selection of actuators for mechatronic systems

System modeling and analysis: Mathematical modeling of mechanical, electrical and electromechanical systems, transfer functions, block diagrams, state-space representation, system response and stability

Control systems for mechatronics: Open-loop and closed-loop control, PID control, digital control basics, microcontrollers and embedded systems, interfacing sensors and actuators, real-time control implementation

Design and applications of mechatronic systems: Integrated system design methodology, case studies such as CNC machines, robotics, automated manufacturing systems, automotive systems, and smart devices, introduction to prototyping and system integration

References

1.	Bolton, W., *Mechatronics- Electronic control systems in Mechanical and Electrical Engineering*, Pearson Education, 2023

2.	Alciatore, D.G., and Histand, M.B., *Introduction to Mechatronics and Measurement Systems*, McGraw Hill Education, 2017
3.	Onwubolu, G., *Mechatronics – Principles and Applications*, Butterworth – Heinemann, 2005
4.	Bishop, R.H., *The Mechatronics Handbook*, Taylor and Francis, 2007
5.	Bell, D.A., *Electronic Instrumentation and Measurements*, Oxford University Press, 2013
6.	Sawhney, A.K., *A Course in Electrical and Electronics Measurements and Instrumentation*, Dhanpat Rai and Co., 2021
7.	Doebelin, E.O., and Manik, D.N., *Doebelin's Measurement Systems*, McGraw Hill Education, 2019
8.	Nise, N.S., *Control Systems Engineering*, Wiley, 2009
9.	Ogata, K., *Modern Control Engineering*, Pearson Education, 2015

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To explain the principles and components of mechatronic systems
CO2	To select appropriate sensors and actuators for engineering applications
CO3	To model and analyze mechatronic systems using mathematical tools
CO4	To design and implement control strategies for mechatronic systems
CO5	To develop integrated mechatronic systems for practical engineering problems

Course Code	:	ME736
Course Title	:	**Corrosion Engineering and Design**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To familiarize students with the fundamental principles of corrosion and its impact on engineering materials and systems
CLO2	To make students understand the thermodynamics and kinetics governing corrosion processes
CLO3	To make students identify different forms of corrosion and analyze their mechanisms
CLO4	To make students learn various corrosion testing, monitoring, and prevention techniques
CLO5	To make students understand corrosion control strategies in industrial applications and design considerations

Course Content

Principles of corrosion phenomenon: Introduction to corrosion, thermodynamics and kinetics of corrosion, electrochemical principles, emf/galvanic series, Pourbaix diagrams, exchange current density, passivity, Evans diagrams, Flade potential

Forms of corrosion: Atmospheric and uniform corrosion, galvanic corrosion, pitting and crevice corrosion, intergranular corrosion, stress corrosion cracking, corrosion fatigue, dealloying, high-temperature oxidation—origin and mechanisms with examples

Corrosion testing and monitoring: Non-electrochemical and electrochemical methods—weight loss method, Tafel extrapolation, linear polarization, electrochemical impedance spectroscopy (EIS), laboratory, semi-plant and field testing methods, corrosion rate measurement and susceptibility testing

Corrosion prevention and control: Materials selection, corrosion-resistant design, coatings and surface treatments, corrosion inhibitors, cathodic and anodic protection methods, economic aspects of corrosion control

Corrosion in industrial systems: Corrosion and its control in power, process, petrochemical, marine, shipbuilding, and fertilizer industries; case studies of corrosion in engineering materials such as concrete structures, stainless steels (duplex and super duplex), ceramics, composites, and polymers; corrosion auditing and corrosion map of India

References

1.	Fontana M.G., *Corrosion Engineering*, McGraw Hill Education, 2005
2.	Jones D.A., *Principles and Prevention of Corrosion*, Pearson Education, 2013
3.	Uhlig H.H., and Revie R.W., *Corrosion and Corrosion Control*, Wiley, 2008

4.	Schweitzer P.A., *Fundamentals of Corrosion: Mechanisms, Causes and Preventative Methods*, CRC Press, 2010
5.	Davis J.R., *Corrosion: Understanding the Basics*, ASM International, 2000
6.	Landolt D., *Corrosion and Surface Chemistry of Metals*, EPFL Press, 2007

Course Outcomes (CO)

At the end of the course, students will be able

CO1	To explain the fundamental principles and mechanisms of corrosion in engineering materials
CO2	To analyze corrosion behaviour using thermodynamic and kinetic concepts
CO3	To identify different forms of corrosion and their causes in practical systems
CO4	To apply corrosion testing and monitoring techniques for evaluation of materials
CO5	To design and recommend appropriate corrosion prevention and control strategies for industrial applications

Course Code	:	ME737
Course Title	:	**Non-Destructive Evaluation**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the basic principles, testing procedures and limitations of various NDT methods used to detect the flaw.
CLO2	To understand different NDT techniques used for identifying the defects.
CLO3	To impart the knowledge for selection of best NDT techniques for a particular product/process.
CLO4	To acquire the comprehensive theoretical knowledge about the procedure of NDE techniques as per industry standards and specification.
CLO5	To understand the applicability of the codes, standards or specifications related to each testing method.

Course Content

Fundamentals of NDT and Material Behaviour: Defect and Discontinuities, Flaws, Inherent, Processing and Service Induced defects. Type of defects in different manufacturing process like welding, etc.

Surface Methods -Visual Inspection - Liquid Penetrant Testing - Magnetic Particle Inspection, Rebar Detector and Cover meter testing.

Volumetric Methods - Electro-Magnetic Methods - Acoustical Methods – Radiographic Methods - Thermal Methods - Optical Methods.

NDT methods used in Industries: Testing of concrete and reinforcement used in structures, testing of walls, steel, wood and plastic used for different structures. Inspection of Weldments. Life time and Quality assessment in pipelines.

NDT Techniques at different stages of manufacturing including raw material inspection, process control and final production inspection. **Codes and Standards**: NDT guidelines in different standards like ASME Section V, AWS D1.1, and ASTM.

Reference Books

1.	*Non-Destructive Testing Handbook*, 4th Edition, 2016.
2.	Baldev Raj, T Jayakumar, and M. Thabasimuthu, *Practical Non-Destructive Testing*, Woodhead Publishing Ltd., UK, 2002
3.	*ASM Handbook, Volume 17, Non-Destructive Evaluation and Quality Control*, ASM International, 2018
4.	C. V. Subramanian, *Practical Ultrasonic*, Narosa Publishing House, Published for ISNT aspirants, 2019

Course Outcomes (CO)

At the end of the course, students will be able to

CO1	Select appropriate NDT methods for flaw detection on the material surface.
CO2	Use the various testing methods for understanding the internal defects of Engineering materials.
CO3	Utilize different NDT techniques to realize the defects and characterization of bulk materials.
CO4	Perform Non-destructive examination of Pipelines and weldments.
CO5	Understand the codes and standards for different NDE techniques.

Course Code	:	ME738
Course Title	:	**Topology Optimization and Generative Design**
Type of Course	:	Programme Elective (PE)
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To understand the principles, mathematical foundations, and engineering significance of topology optimization and generative design methodologies.
CLO2	To develop optimization models for structural, thermal, and multidisciplinary engineering applications using finite element methods.
CLO3	To Apply topology optimization algorithms and generative design workflows using modern CAD/CAE software tools.
CLO4	To incorporate manufacturing constraints, material selection, sustainability, and additive manufacturing considerations into optimized product development.
CLO5	To analyze, validate, and interpret optimized engineering designs for real-world industrial applications and research problems.

Course Content

Fundamentals of Optimization and Design Evolution: Introduction to Optimization, Fundamentals of Structural Optimization, Introduction to Generative Design, Historical Development and Industrial Need, Software Introduction.

Mathematical and Finite Element Foundations of Topology Optimization: Mathematical Foundations, Finite Element Method for Optimization, Density-Based Topology Optimization Methods, Level Set and Evolutionary Methods, Numerical Implementation.

Generative Design Methodologies and AI-Assisted Design: Generative Design Workflow, Artificial Intelligence in Design, Multi-objective and Multidisciplinary Optimization, Additive Manufacturing and Design Freedom, Sustainability and Material Efficiency.

Software-Based Topology Optimization and Generative Design Applications: Topology Optimization Using Commercial Software, **Practical Exercises:** Cantilever beam optimization, Bracket design optimization, Connecting rod optimization, Heat sink optimization, Lightweight structural frame design. **Generative Design Applications,** Reverse Engineering and Digital Twin Integration.

Validation and Experimental Correlation: Prototype fabrication using additive manufacturing, Experimental testing methods, Structural validation, Performance comparison with conventional designs.

References

1.	Martin P. Bendsøe and Ole Sigmund, *Topology Optimization: Theory, Methods, and Applications,* Springer, 2nd Edition, 2004.
2.	George I. N. Rozvany and Tomasz Lewiński, *Topology Optimization in Structural and Continuum Mechanics,* Springer, 2014
3.	Behrooz Hassani and Ernest Hinton, Homogenization and Structural Topology Optimization: Theory, Practice and Software, Springer, 1999.
4.	Yi Min Xie, *Generalized Topology Optimization for Structural Design,* Springer Nature, 2025.
5.	Nikolaos Kladovasilakis, Konstantinos Tsongas and Dimitrios Tzetzis, *Innovations in Topology Optimization: With Applications in Materials, Product Design, and Manufacturing,* Publisher: Springer, 2025
6.	Hartmut Bohnacker, Benedikt Groß, Julia Laub and Claudius Lazzeroni, *Generative Design: Visualize, Program, and Create with Processing,* Princeton Architectural Press, 2012.

Course Outcomes (CO)

At the end of the course, students will able to

CO1	Explain various topology optimization techniques, optimization algorithms, and generative design concepts used in engineering design.
CO2	Formulate objective functions, constraints, and finite element models for topology optimization problems.
CO3	Perform topology optimization and generative design using commercial software for lightweight and high-performance product development.
CO4	Evaluate manufacturability, structural performance, sustainability, and additive manufacturing compatibility of optimized designs.
CO5	Design innovative engineering components and systems using topology optimization and generative design approaches for industrial applications.

LIST OF ONLINE COURSES

Sl. No.	Course of Study	Platform
1.	Ergonomics in Automotive Design	NPTEL
2.	Fundamentals of Automotive Systems	NPTEL
3.	Principles of Engineering System Design	NPTEL
4.	Ergonomics Research Techniques	NPTEL
5.	Design, Technology and Innovation	NPTEL
6.	Understanding Incubation and Entrepreneurship	NPTEL
7.	System Design for Sustainability	NPTEL
8.	Interactive Design	NPTEL
9.	Introduction To Launch Vehicle Analysis and Design	NPTEL
10.	Introduction to Aircraft Design	NPTEL
11.	Computational Science in Engineering	NPTEL
12.	Aircraft Design	NPTEL
13.	Aerospace Structural Analysis	NPTEL
14.	Fundamentals of Theoretical and Experimental Aerodynamics	NPTEL
15.	Aircraft Structures	NPTEL
16.	Space Flight Mechanics	NPTEL
17.	Product Engineering and Design Thinking	NPTEL
18.	Design Practices for Intelligent Product Design	NPTEL
19.	Thermodynamics of Materials	NPTEL
20.	Machine Learning for Engineering and Science Applications	NPTEL

Any other relevant online courses of minimum 12-weeks duration can be opted by the M. Tech. Engineering Design Students as an open elective course with the prior approval of the Programme Coordinator and the Head, Mechanical Engineering Department.