CURRICULUM & SYLLABI

M.Tech. MACHINE DESIGN

Effective from AY: 2024-25



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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Vision and Mission of the Institute
National Institute of Technology Warangal

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department
MECHANICAL Engineering

VISION

To be a global knowledge hub in mechanical engineering education, research, entrepreneurship and industry outreach services.

MISSION

- Impart quality education and training to nurture globally competitive mechanical engineers.
- Provide vital state-of-the-art research facilities to create, interpret, apply and disseminate knowledge.
- Develop linkages with world class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.

Program: M.Tech. Machine Design

Program Educational Objectives

PEO-1	Analyze the concepts and tools for design and development of machine components and systems.
PEO-2	Analyze the physical systems and establish schematics and mathematical models
PEO-3	Design, analyze and simulate mechanical components and systems.
PEO-4	Develop life skills to become design professionals, administrators and Academicians**.**
PEO-5	Engage in lifelong learning to adopt socio-economic -technological developments

Program Articulation Matrix

PEO / Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4	PEO-5
Impart quality education and training to nurture globally competitive mechanical Engineers	3	3	2	2	2
Provide vital state-of-the-art research facilities to create, interpret, apply and disseminate knowledge	3	3	2	2	2
Develop linkages with world class educational institutions and R&D organizations for excellence teaching, research and consultancy services	3	3	2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Program: M.Tech. Machine Design

Program Outcomes

PO-1	Carryout independent research/investigation and development work to solve practical problems
PO-2	Write and present a substantial technical report/document
PO-3	Demonstrate a degree of mastery in machine design at a level higher than the bachelors programme
PO-4	Use state of art tools and techniques to model and analyze machine components
PO-5	Design, develop and evaluate mechanical components and systems
PO-6	Engage in lifelong learning adhering to professional, ethical, legal, safety, environmental and societal aspects for career excellence.

CURRICULUM
M.Tech. Machine Design

1st Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME46001	Mechanical Design	3-0-0	3
2	ME46003	Mechanical Vibrations	3-0-0	3
3	ME46005	Advanced Materials for Design	3-0-0	3
4		Professional Elective- I	3-0-0	3
5		Professional Elective- II	3-0-0	3
6	ME46007	Machine Dynamics Laboratory	0-1-2	2
7	ME46009	Numerical Computation Laboratory	0-1-2	2
			Total Credits	**19**

2nd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME46002	Product Design and Development	3-0-0	3
2	ME46004	Finite Element Analysis for Design	3-0-0	3
3		Professional Elective- III	3-0-0	3
4		Professional Elective- IV	3-0-0	3
5		Professional Elective- V	3-0-0	3
6	ME46006	Modeling and Analysis Laboratory	0-1-2	2
7	ME46008	Composite and Tribology Laboratory	0-1-2	2
8	ME46096	Minor Project	0-0-0	2
			Total Credits	**21**

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME47089	Seminar & Technical Writing	0-0-0	2
2	ME47091	Summer Internship/Research Experience	0-0-0	2
3	ME47093	Comprehensive Viva-Voce	3-0-0	2
4	ME47097	Dissertation: Part– A	0-0-0	8
			Total Credits	**14**

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME47098	Dissertation: Part– B	0-0-0	12
			Total Credits	**12**

Professional Elective Courses:

Professional Elective-I & II		
S.No.	**Code**	**Course Title**
1	ME46021	Computer Aided Geometric Design
2	ME46023	Analysis and Synthesis of Mechanisms
3	ME46025	Theory of Plates and Shells
4	ME46027	Mathematical Methods in Engineering
5	ME46029	Mechanics of Composite Materials
6	ME46031	Automatic Control
7	ME46033	Systems Thinking for Engineering Applications

Professional Elective- III, IV & V		
S.No.	**Code**	**Course Title**
1	ME46022	AI/ML for Engineering Analysis
2	ME46024	Condition Monitoring and Fault Diagnostics
3	ME46026	Fracture Mechanics
4	ME46028	Optimization Methods for Engineering Design
5	ME46030	Robotics
6	ME46032	Rotordynamics
7	ME46034	Tribology in Design
8	ME46036	Characterization of Engineering Materials
9	ME46038	Smart Materials and Sensors
10	ME46040	Noise, Vibrations and Harshness
11	ME 26030	Product Life Cycle Management

The Overall Credit Structure

Course Category	Credits
Program Core	23
Professional Elective	15
Minor Project	2
Seminar and Technical Writing	2
Summer Internship/ Research Experience	2
ComprehensiveViva-Voce	2
Dissertation	20
Total Graded Credit Requirement	**66**

SYLLABI

M.Tech. Machine Design

1st Semester

ME46001 **3-0-0 (3)**

MECHANICAL DESIGN

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze material failure modes and establish various stresses and failure theories on static and dynamic loading
CO-2	Analyze high, low cycle fatigue and interpretation of data by combined loading
CO-3	Design and predict the fracture strength of mechanical components
CO-4	Design mechanical components involving contacts avoiding the surface failures.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	2	2	2
CO-2	3	3	2	2	2	2
CO-3	3	2	2	3	2	2
CO-4	3	2	2	2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Material selection for design; Engineering Design process and the role of materials; Materials classification and their properties; Types of Material Failure – Elastic & Plastic Deformation, Creep deformation. The role of failure prevention analysis in Mechanical Design, Modes of Mechanical failure and their identification

Combined stress theories of failure: State of stress, Differential equations of equilibrium and relation between stress and strain. Static loading, Dynamic loading. Theories of failure and their Use in Design.

High-Cycle and low cycle fatigue system: Fatigue failure theories and models; Fatigue life; Estimation of theoretical fatigue strength; Correction factors to the theoretical fatigue strength; Stress concentration; Cumulative damage and life exhaustion; Effect of mean stress on the fatigue failure; Designing for fully reversed uniaxial stresses; Designing for fluctuating uniaxial stresses; Designing for multi-axial stresses in fatigue.

Introduction to Fracture Mechanics, Creep mechanisms and their principles for Design: Theoretical cohesive strength, Griffith crack theory, Strain energy release rate, Energy release rate and stress field approaches, Fracture toughness of engineering alloys, Crack tip plasticity effects, Use of Fracture Mechanics principles for design. Fatigue crack growth properties, Applications to life analysis and design, Damage Tolerance and Fracture Control Applications in Design. Creep mechanisms - day to day examples; Temperature dependence of creep; Creep and Super plasticity: Correlations to determine rupture time under creep condition – Larson – Miller, Manson and Haferd, Orr-Sherby Dorn.

Design for failure prevention: Surface Geometry; Mating surfaces; Friction; Surface failures - Adhesive wear, Abrasive wear, Corrosion wear, Surface fatigue wear; Static and Dynamic Contact stresses – Spherical contact, Cylindrical contact and General contact, Design Case Studies – Ball bearing, Cylindrical roller bearing, Cam-follower contact.

Learning Resources:

Text Books:

1. Jacks A. Collins, Failure of Materials in Mechanical Design: Analysis, Prediction and Prevention, John Wiley & Sons, 1993, 2nd Edition.
2. Robert L Norton, Machine design an integrated approach, Pearson Education, 2018, Fifth Edition.

Reference Books:

1. L.S. Srinath, Advanced Mechanics of Solids, TMH, 2017, 3rd Edition
2. Richard G. Budynas, J Keith Nisbett, Shigley's Mechanical Engineering Design, Mc Graw Hill, 2014, Tenth Edition.
3. Prashanth Kumar, Elements of Fracture Mechanics, Mc-Graw Hill, 2017.
4. Norman E. Dowling, Mechanical behavior of Materials, Pearson, 2012, 4th edition.
5. S. Suresh, Fatigue of Materials, Cambridge University Press, 2012, 2nd Edition.
6. Ashby, M.F., Materials Selection in Design, Butterworth-Heinemann, 2016, 5TH Edition.
7. Failure Analysis and Prevention (ASM Hand Book), Metals Hand Book, Vol.11, 2002, 9th Edition.

ME46003 **3-0-0 (3)**

MECHANICAL VIBRATIONS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze the causes and effects of vibrations in mechanical systems and identify discrete and continuous systems.
CO-2	Model the physical systems into schematic models and formulate the governing equations of motion.
CO-3	Compute the free and forced vibration responses of multi degree of freedom systems through modal analysis and interpret the results.
CO-4	Analyse and design systems involving unbalance, transmissibility, vibration isolation and absorption.
CO-5	Analyse and design to control and reduce vibration effects in machinery.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	2		2	2
CO-2	3	3	3		2	2
CO-3	2	3	2	2	3	2
CO-4	3	3	2		3	2
CO-5	2	3	2	2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Causes and effects of vibration, Classification of vibrating system, Discrete and continuous systems, degrees of freedom, Identification of variables and Parameters, Linear and nonlinear systems, linearization of nonlinear systems, Physical models, Schematic models and Mathematical models.

Single Degree of Freedom (SDF) systems: Formulation of equation of motion: Newton –Euler method, De Alembert's method, Energy method, Free Vibration: Undamped Free vibration response, Damped Free vibration response, Case studies on formulation and response calculation. Forced vibration response of SDF systems: Response to harmonic excitations, solution of differential equation of motion, Vector approach, Complex frequency response, Magnification factor Resonance, Rotating/reciprocating unbalances.

Dynamics of Rotors: Whirling of rotors, Computation of critical speeds, influence of bearings, Critical speeds of Multi rotor systems.

Design case studies: Design case studies dealing with Transmissibility of forces and motion, Vehicular suspension, Analysis of Vehicles as single degree of freedom systems -vibration transmitted due to unevenness of the roads, preliminary design of automobile suspension. Design of machine foundations and isolators.

Two degree of freedom systems: Introduction, Formulation of equation of motion: Equilibrium method, Lagrangian method, Case studies on formulation of equations of motion, Free vibration response, Eigen values and Eigen vectors, Normal modes and mode superposition, Coordinate coupling, decoupling of equations of motion, Natural coordinates, Response to initial conditions, coupled pendulum, free vibration response case studies, Forced vibration response, Automobile as a two degree of freedom system – bouncing and pitching modes undamped vibration absorbers, Case studies on identification of system parameters and design of undamped vibration absorbers. Analysis and design of damped vibration absorbers.

Multi degree of freedom systems: Introduction, Formulation of equations of motion, Free vibration response, Natural modes and mode shapes, Orthogonally of modal vectors, normalization of modal vectors, Decoupling of modes, modal analysis, mode superposition technique, Free vibration response through modal analysis, Forced vibration analysis through modal analysis, Modal damping, Rayleigh's damping, Introduction to experimental modal analysis.

Continuous systems: Introduction to continuous systems, discrete vs continuous systems, Exact and approximate solutions, free vibrations of bars and shafts, Free vibrations of beams, Forced vibrations of continuous systems Case studies, Approximate methods for continuous systems and introduction to Finite element method.

Vibration control in structures: Introduction, State space representation of equations of motion. Passive control, active control and semi active control, Free layer and constrained damping layers, Piezo electric sensors and actuators for active control, semi active control of automotive suspension systems.

Learning Resources:

Text Books:

1. L. Meirovich, Elements of Vibration Analysis, Tata Mc-Grawhill, 2007, 2nd Edition.
2. Singiresu S Rao, Mechanical Vibrations, Pearson education, 2011, 4th Edition.

Reference Books:

1. W.T, Thomson, Theory of Vibration, CBS Publishers, 2002, 3rd Edition.
2. Clarence W. De Silva, Vibration: Fundamentals and Practice, CRC Press LLC, 2000
3. Venkatachalam R., Mechanical Vibrations, PHI Publications, 2018

ME46005 **3-0-0 (3)**

ADVANCED MATERIALS FOR DESIGN

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe the various advanced materials and their unique properties used in industries.
CO-2	understand the application of advanced composites, smart materials, FGMS, and nano-materials.
CO-3	Understand the structure and function of various materials such as FGMs, composites, Shape Memory Alloys etc.
CO-4	Apply the understanding gained for designing materials for design applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	2	2	2
CO-2	3	2	2	2	3	2
CO-3	3	3	3	3	2	2
CO-4	3	2	2	2	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Composite Materials: Composite constituents; principles of fibre- reinforced composites, composites classes, PMCs, MMCs, CMCs, CCCs, hybrid composites, PFMS, fibers and matrices, different types of fibers, whiskers, different matrices materials, polymers, metal, ceramic matrices, toughening mechanism, interfaces, blending and adhesion, Natural fiber composites, Important properties and applications of these materials.

Nanomaterials: Origin of nanotechnology, Classification of nanomaterials, Physical, chemical, electrical, mechanical properties of nanomaterials. Nano-materials for product design; mechanical and thermal properties of nano-composite materials. Preparation of nanomaterials by plasma arcing, physical vapour deposition, chemical vapour deposition (CVD), Sol-Gel, electro deposition, ball milling, carbon-nano tubes(CNT).Synthesis, preparation of nanotubes, nanosensors, Quantum dots, nanowires, nanobiology, nanomedicines.

Functional Graded Material: Introduction to Functionally Graded Materials (FGM), Types of Functionally Graded Materials and their Areas Of Application.- Processing Methods of Functionally Graded Materials.- Additive Manufacturing of Functionally Graded Materials.- Experimental Analysis of Functionally Graded Materials from Laser Deposition Process (Case Study), Structural and functional characterization of FGM, Properties required for low temperature applications, Materials available for low temperature applications, Requirements of materials for high temperature applications, Materials available for high temperature applications, Applications of low and high temperature materials.

Shape Memory Alloys (SMA): Phenomena & mechanisms of temperature-controlled shape memory effect, critical temperatures, stress effect on critical temperatures, mechanical properties of SMA at different phases and temperatures, shape memory and superelasticity, major impediments to applications of SMA.

Ceramics and Bio Glasses: Overview of biomaterials Bio-ceramics: Nearly inert ceramics, bio-reactive glasses and glass ceramics, porous ceramics; Calcium phosphate ceramics: grafts, coatings Physico-chemical surface modification of materials used in medicine. biomaterials in ophthalmology, orthopedic implants, dental materials, other advanced materials.

Advanced material: new advances materials

Learning Resources:

Text Books:

1. T. W. Clyne, D. Hull, An Introduction to Composite Materials, Cambridge University Press, 2019, 3rd Edition
2. Dieter Vollath, Nanomaterials: An Introduction to Synthesis, Properties and Applications, Wiley, 2013, 2nd Edition
3. Rasheedat Modupe Mahamood, Esther Titilayo Akinlabi, Functionally Graded Materials, Springer, 2017, 1st Edition
4. P.K. Kumar, D.C. Lagoudas, Dimitris C. Lagoudas, Shape Memory Alloys: Modeling and Engineering Applications, Springer, 2008, 1st Edition
5. Jones, Julian;Clare, Alexis;Alexis G. Clare, Bio-Glasses: An Introduction, Wiley, 2012, 1st Edition

Reference Books:

1. Pulak M. Pandey, Sandeep Rathee, Manu Srivastava, Prashant K. Jain, Functionally Graded Materials (FGMs): Fabrication, Properties, Applications, and Advancements, CRC Press, 2021, 1st Edition
2. Sri Bandyopadhyay, Raghavendra Gujjala, Toughened Composites Micro and Macro Systems, CRC Press, 2022, 1st Edition

ME46007 **0-1-2 (2)**

MACHINE DYNAMICS LABORATORY

Pre-Requisites: **None**

Course Outcomes:

CO-1	Study and analyze the kinematics of different mechanisms.
CO-2	Evaluate the vibration parameters using undamped and damped free and forced vibrations.
CO-3	Estimate the unbalance and balance the rotors.
CO-4	Identify the natural modes and study the influence of initial conditions on the response of a two degree of freedom systems.
CO-5	Determine the critical speed of shafts with short and long bearings.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3		2	
CO-2	3	3	3		2	
CO-3	3	3	3		2	
CO-4	3	3	3		2	
CO-5	3	3	3		2	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments conducted in this laboratory:

1. Undamped Free Vibrations
2. Damped Free Vibrations of one degree freedom system
3. Damped Free Vibrations of two degree freedom system
4. Vibrations of Continuous System: A Cantilever Beam
5. Balancing of Rotors: Rotor Balancing Machine
6. Balancing of Reciprocating Machines: Balancing a Twin Cylinder Engine (A Locomotive Engine)
7. Critical speeds of shafts with hinged and fixed end conditions
8. Tuning of Dynamic Absorber
9. Case studies on mechanisms and inversions
10. Mini project

Learning Resources:

Text Books:

1. Laboratory Instruction Manual.

ME46009 **0-1-2 (2)**

NUMERICAL COMPUTATION LABORATORY

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply built-in functions in MATLAB/ SCILAB to solve numerical problems.
CO-2	Develop code for solving problems involving different types of mathematical models and equations (ODE, PDE, Linear and nonlinear equations).
CO-3	Solve simulation problems encountered in mechanical design, vibration analysis and CAD
CO-4	Model a system and Develop a simulation code towards a mini project

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2		3	2	1	2
CO-2	3		3	3	2	2
CO-3	3		3	3	3	2
CO-4	3	2	3	3	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments conducted in this laboratory:

1. Introduction to MATLAB and practice
2. Practice session on handling basic arithmetic etc.
3. Writing codes with control loops, functions and scripts
4. Developing codes for visualization and plotting
5. Solving problems involving linear and nonlinear equations
6. Solving problems involving curve fitting and interpolations
7. Solving problems involving ordinary and partial differential equations
8. Solving problems related to optimization
9. Solving problems involving numerical differentiation and integrations
10. Practice session
11. Introduction to Simulink
12. Case studies and working on projects
13. Case studies and working on projects
14. Case studies and working on projects

Learning Resources:

Text Books:

1. Laboratory Instruction Manual.

2nd Semester

ME46002 **3-0-0 (3)**

PRODUCT DESIGN AND DEVELOPMENT

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop conceptual product models using creativity and product design techniques
CO-2	Apply embodiment principles in product development process.
CO-3	Develop products by considering the social, environmental and ethical concerns.
CO-4	Experience by developing CAD/ physical models using the concepts of product design theory.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	3	3	3	2
CO-2	2	3	3	3	2	2
CO-3			1			3
CO-4	3	3	3	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Design thinking philosophy. product design context- types of designs, design method vs scientific method, considerations of a good design, design activities/ process, product life and technological insertion cycles, organizational structures, business models, design in team behavior and dynamics. sketching practice and course project assignment

Problem identification: Need analysis, customer study and need identification tools, product quality, classification of customer requirements, kano diagram, benchmarking, establishing engineering characteristics- QFD- House of Quality (HOQ), product design specification

Gathering Information: Transformation from data to knowledge, types, and sources of information, information gathering for research and product design, intellectual property rights- classification, patent searching, stages of patent filing. codes and standards

Concept Generation/Improvement and Decision making: Creative thinking models, creative thinking aids and barriers, structured and unstructured creative design methods/theories- brainstorming techniques, random input technique and Synectics, concept map, functional decomposition, morphological analysis, TRIZ, axiomatic design, practice exercises. decision-making theories- criteria-based selection, Pugh's concept, AHP.

Embodiment and Detailed Design: Product architecture, configuration and parametric design concepts, detailed design, modeling and simulation, legal and ethical issues in design. DFX, course project reviews

Learning Resources:

Text Books:

1. George E Dieter, Engineering Design, Publisher, McGraw Hill, 2013, 5th edition.

Reference Books:

1. Kevin N. Otto, Kristin L. Wood, Product Design: Techniques in Reverse Engineering and New Product Development, Pearson Education, 2004.
2. W. Ernest Eder, S. Hosendl, Design Engineering, CRC Press, 2008

Other Suggested Readings:

1. https://nptel.ac.in/courses/107/103/107103082/

ME46004 **3-0-0 (3)**

FINITE ELEMENT ANALYSIS FOR DESIGN

Pre-Requisites: **None**

Course Outcomes:

CO-1	Make use of the concept of finite element method for solving machine design problems
CO-2	Solve problems in 1-D structural systems involving bars, trusses, beams and frames.
CO-3	Develop 2-D and 3-D FE formulations involving triangular, quadrilateral elements and higher order elements.
CO-4	Apply the knowledge of FEM for stress analysis, model analysis, heat transfer analysis and flow analysis.
CO-5	Develop algorithms and FE code for solving design problems and adapt commercial packages for complex problems.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3		2		2	2
CO-2	2		2		2	
CO-3			2	2	3	
CO-4	3		3	2	3	2
CO-5	3	2	3	3	3	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Historical Perspective of FEM and applicability to mechanical engineering design problems.

Mathematical Models and Approximations: Review of elasticity. Mathematical models for structural problems: Equilibrium of continuum-Differential formulation, Energy Approach- Integral formulation: Principle of Virtual work - Variational formulation. Overview of approximate methods for the solution of the mathematical models, Residual methods and weighted residual methods, Ritz, Rayleigh-Ritz and Gelarkin's methods. Philosophy of solving continuum problems using Finite Element Method.

Finite Element Formulation: Generalized FE formulation based on weightedresidual method and through minimization of potential, displacement based formulation,Concept of discretization, Interpolation, Formulation of Finite element characteristic matrices and vectors, Compatibility conditions, Assembly and boundary considerations.

Finite Element Analysis for One Dimensional Structural problems: Structuralproblems with one dimensional geometry. Bar element: formulation of stiffness matrix,consistent and lumped load vectors. Boundary conditions and their incorporation:Elimination method, Penalty Method, Introduction to higher order elements and their advantages and disadvantages. Formulation for Truss elements, Case studies involving hand calculations with an emphasis on assembly, boundary conditions,contact conditions and multipoint constraints.

Beams and Frames: Review of bending of beams, higher order continuity (C^0 and C^1 Continuity), interpolation for beam elements and formulation of FE characteristics, Plane and space frames and examples problems involving hand calculations. Algorithmic approach for developing computer codes involving 1-D elements.

Two dimensional Problems: Interpolation in two dimensions, natural coordinates, Isoparametric representation, Concept of Jacobian. Finite element formulation for plane stress plane strain and axi-symmetric problems; Triangular and Quadrilateral elements, higher order elements, sub-parametric, Isoparametric and superparametric elements. Formulation of plate bending elements using linear and higher order bending theories, Shell elements, General considerations in finite element analysis of design

problems, Choosing an appropriate element and the solution strategies. Introduction to pre and post processing of the results and analysis.

Three Dimensional Problems: Finite element formulation for 3-D problems, mesh preparation, tetrahedral and hexahedral elements, case studies.

Dynamic Analysis: FE formulation in dynamic problems in structures using Lagrangian Method, Consistent and lumped mass models, Formulation of dynamic equations of motion, Modelling of structural damping and formulation of damping matrices, Model analysis, Mode superposition methods and reduction techniques.

FEM in Heat Transfer and Fluid Mechanics problems: Finite element solution for one dimensional heat conduction with convective boundaries. Formulation of element characteristics and simple numerical problems. Formulation for 2-D and 3-D heat conduction problems with convective boundaries. Introduction to thermo-elastic contact problems. Finite element applications in potential flows; Formulation based on Potential function and stream function. Case studies.

Algorithmic Approach for problem solving: Algorithmic approach for Finite element formulation of element characteristics, Assembly and incorporation of boundary conditions. Guidelines for code development. Introduction to commercial Finite Element software packages like ANSYS.

Learning Resources:

Text Books:

1. Singiresu S.Rao, Finite element Method in Engineering, Elsevier, 2012, 5th edition,
2. Seshu P, Textbook of Finite Element Analysis, PHI. 2004.

Reference Books:

1. Reddy, J.N., Finite Element Method in Engineering, Tata McGraw Hill, 2017
2. Zeincowicz, The Finite Element Method, 4 Vol set, Elsevier, 2007, 4th Edition.

ME46006 **0-1-2 (2)**

MODELING AND ANALYSIS LABORATORY

Pre-Requisites: **None**

Course Outcomes:

CO-1	Build 2D and 3D objects using a modeling software.
CO-2	Generate 3D parts and assemblies using a modeling software.
CO-3	Solve structural problems using finite element software.
CO-4	Solve advanced practical problems using finite element software.
CO-5	Execute mini project involving both modeling and analysis

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	3	2		
CO-2	3	3	3	3	3	2
CO-3	3	3	3	2	3	2
CO-4	3	3	3	3	3	3
CO-5	3	3	3	2	3	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments conducted in this laboratory:

1. Introduction to Modeling software and working with features like Extrude & Revolve
2. Model solids with features like Hole, Round, Chamfer and Rib
3. Model solids with features like Pattern, Copy, Rotate, Move and Mirror
4. Advanced modeling tools (Sweep, Blend, Variable section Sweep etc)
5. Assembly modelling
6. Introduction to FEA software, Solution of 1-D bar problems
7. Solution of Beam problems with various boundary and loading condition
8. Modelling of Trusses and Frames, element types and mesh independence
9. Solution of plane problems: Plane strain, plane stress and axis-symetric
10. Solution of Heat conduction problem
11. Dynamic Analysis
12. Modelling of Fracture and Indentation problems
13. Coupled analysis. Ex. Thermo-elastic analysis
14. Topology optimization
15. Modelling of multi-layer materials, Sandwich structures, Composites and FGM
16. Scripting and automation

Learning Resources:

Text Books:

1. Laboratory Instruction Manual.

ME46008 **0-1-2 (2)**

COMPOSITE AND TRIBOLOGY LABORATORY

Pre-Requisites: **None**

Course Outcomes:

CO-1	Fabricate different type of advanced materials such as composites and FGM
CO-2	Analyze different mechanical properties of the material
CO-3	Evaluate the tribological properties of the lubricant
CO-4	Analyze different wear behaviour of materials

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	3	2	1	2
CO-2	2	3	3	3	2	3
CO-3	2	1	3	3	3	3
CO-4	1	2	3	3	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments conducted in this laboratory:

1. Fabrication of particulate based polymer composite
2. Fabrication of fiber reinforced polymer composite
3. Fabrication of one dimensional functionally graded material (FGM)
4. Fabrication of bio-glasses by melt-quenching process
5. Determination of tensile strength of composite and FGM material
6. Determination of compressive strength of composite and FGM material
7. Determination of flexural strength of composite and FGM material
8. Measurement of erosive wear rate by using air jet erosion test rig
9. Determination of friction and wear properties of selected lubricant using four ball tester
10. Determination of maximum load carrying capacity (extreme pressure test) of selected lubricant using four ball tester
11. Determination of adhesive wear under dry condition using pin on disk friction and wear test rig
12. Determination of abrasive wear using dry sand abrasive wear test rig
13. Determination of adhesive wear under lubricated condition using pin on disk friction and wear test rig
14. Surface modification of the material to enhance mechanical and tribological properties by Nd:YAG Laser (Demo)

Learning Resources:

Text Books:

1. Laboratory Instruction Manual.

ME 46096 **0-0-0 (2)**

Minor Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world projects
CO-2	Plan and monitor project tasks individually or as a team
CO-3	Demonstrate practical experience in project execution
CO-4	Communicate project findings clearly through reports and presentations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3		3	3	3	3
CO-2	3	2	3	2	2	3
CO-3	3		3	2	3	3
CO-4		3	3			3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Identification of Problem Domain	
II	Study of Existing Systems and establishing clear objectives	
III	Planning of project and work distribution within the team	
IV	Proper Documentation and Technical Writing	
V	Presentation and Response to questions	

Evaluation Criteria-CO Mapping

CO / Criteria	CO-1	CO-2	CO-3	CO-4
I	X			
II	X			
III		X	X	
IV				X
V				X

3rd Semester

ME47089 **0-0-0 (2)**

SEMINAR & TECHNICAL WRITING – I

Pre-Requisites: **None**

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3				2
CO-2	2	3	2			2
CO-3	2	3	2	2		2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Clarity on the topic	
II	List of lectures attended	
III	Report	
IV	Presentation	
V	Response to questions	

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3
I	X		
II	X		
III		X	
IV			X
V			X

ME47091 **3-0-0 (3)**

SUMMER INTERNSHIP/RESEARCH EXPERIENCE

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	1	3		2	3
CO-2	2	1	2		2	3
CO-3		2				3
CO-4		3				3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Every student has to undergo either a Summer Internship / EPICS / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The EPICS/research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Relevance of the area of work	
II	Performance of the Task	
III	Crucial learnings from the work	
IV	Report Preparation	
V	Presentation and Response to questions	

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X
V				X

ME47093 **0-0-0 (2)**

COMPREHENSIVE VIVA

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the knowledge gained in the course work
CO-2	Identify principles of design of mechanical systems and controls
CO-3	Demonstrate the ability in problem solving and to communicate effectively.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3		3	2		3
CO-2	3		3	3	2	3
CO-3	3		3	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

In Comprehensive viva-voce each student will be evaluated for their overall comprehension of the course work and laboratory training that they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots, schematics, write simple code etc. as questioned by the panel. Assessment will be done by the panel based on the student response

ME47097 **0-0-0 (8)**

DISSERTATION: PART – A

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a topic in advanced areas of machine design
CO-2	Review literature to identify gaps and define objectives and scope of the work
CO-3	Employ the ideas from literature and develop research methodology
CO-4	Develop a model, experimental set-up and/or computational techniques necessary to meet the objectives.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	1		3
CO-2	3	2	3	1		3
CO-3	3	3	3	3	3	3
CO-4	3	3	3	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – A will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Selection of Topic	
II	Literature Survey	
III	Defining the Objectives and Solution Methodology	
IV	Performance of the Task	

Evaluation Criteria - CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X

Refer to the M.Tech. – Regulations for any further information regarding mid-term review and end semester evaluation, etc.

4th Semester

ME47098 **0-0-0 (15)**

DISSERTATION: PART – B

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the materials and methods for carrying out experiments/develop a code
CO-2	Execute the research methodology with a concern for society, environment and ethics
CO-3	Analyse, discuss and justify the results/trends and draw valid conclusions
CO-4	Prepare the report as per recommended format and present the work orally adhering to stipulated time
CO-5	Explore the possibility to publish/present a paper in peer reviewed journals/conference without plagiarism

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2		3	3	2	3
CO-2	2		3	3	2	3
CO-3	3		3	3	2	3
CO-4	3	3	3	3	3	3
CO-5	3	3	3			3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – B will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria as a continuation of Dissertation Part A. Weightage for each criterion will be determined by the panel and will be informed to the students.

Task	Description	Weightages
IV	Performance of the Task	
V	Dissertation Preparation	
VI	Review (Presentation & Understanding)	
VII	Viva-Voce	
VIII	Publications /Possibility of publication	

Evaluation Criteria-CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4	CO5
IV	X	X			
V				X	
VI			X		
VII				X	
VIII					X

Refer to the M.Tech. – “Refer to M.Tech. – Regulations for any further information regarding Mid-term review, End Sem evaluation, Template for report preparation and plagiarism”

Professional Electives

ME46021 **3-0-0 (3)**

COMPUTER-AIDED GEOMETRIC DESIGN

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply geometric transformations and projection methods in CAD
CO-2	Develop geometric models to represent curves
CO-3	Design surface and solid models for engineering design
CO-4	Apply mesh generation techniques for engineering analysis

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3		3	3	2	2
CO-2	3		3	3	2	2
CO-3	3	2	3	3	3	2
CO-4	3	2	3	3	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction to CAE, CAD. Role of CAD in Mechanical Engineering, Design process, software tools for CAD, Geometric modelling.

Transformations in Geometric Modeling: Introduction, Translation, Scaling, Reflection, Rotation in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations. Computer-Aided assembly of rigid bodies, Applications of transformations in design and analysis of mechanisms, etc. Implementation of the transformations using computer codes.

Projections: Projective geometry, transformation matrices for Perspective, Axonometric projections, Orthographic and Oblique projections. Implementation of the projection formulations using computer codes.

Introduction to Geometric Modeling for Design: Introduction to CAGD, CAD input devices, CAD output devices, CAD Software, Display Visualization Aids, and Requirements of Modelling.

Curves in Geometric Modeling for Design: Differential geometry of curves, Analytic Curves, PC curve, Ferguson's Cubic Curve, Composite Ferguson, Curve Trimming and Blending. Bezier segments, de Casteljau's algorithm, Bernstein polynomials, Bezier-subdivision, Degree elevation, Composite Bezier. B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS, Conversion of one form of curve to other. Implementation of the all the curve models using computer codes in an interactive manner.

Surfaces in Geometric Modeling for Design: Differential geometry of surfaces, Parametric representation, Curvatures, Developable surfaces. Surfaces entities (planar, surfac of revolution, lofted etc). Free-for surface models (Hermite, Bezier, B-spline surface). Boundary interpolating surfaces (Coon's). Implementation of the all the surface models using computer codes.

Solids in Geometric Modeling for Design: Solid entities, Boolean operations, Topological aspects, Invariants. Write-frame modeling, B-rep of Solid Modelling, CSG approach of solid modelling. Popular modeling methods in CAD softwares. Data Exchange Formats and CAD Applications:

Meshing Methods for Engineering Analysis: FEM, Meshing, Quality of meshing, Mesh generation methods

Learning Resources:

Text Books:

1. Michael E. Mortenson, Geometric Modeling, Tata McGraw Hill, 2013.

2. Saxena and B. Sahay, Computer-Aided Engineering Design, Anamaya Publishers, New Delhi, 2005.

Reference Books:

1. Rogers, David F.Morgan, An introduction to NURBS: with historical perspective, Kaufmann Publishers, USA, 2001.
2. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, TMH, 2008.
3. Kunwoo Lee, Principles of CAD/CAM/CAE systems, Addison-Wesley, 1999.

ME46023 **3-0-0 (3)**

ANALYSIS AND SYNTHESIS OF MECHANISMS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand basic mechanisms and machines and formulate the design problem.
CO-2	Develop analytical equations for relative position, velocity and acceleration of all moving links.
CO-3	Analyze Simple and Complex mechanisms.
CO-4	Apply the knowledge of Kinematic theories to practical problems of mechanism design and synthesis.
CO-5	Design higher pair kinematic linkages for a given application.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	3	2	1
CO-2	3	3	3	3	3	3
CO-3	2	3	3	3	3	3
CO-4	3	3	3	2	2	2
CO-5	3	3	3	3	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Review of kinematic chains, equivalent chains, and their inversions.

Kinematic Analysis: Review on graphical methods**,** algebraic position analysis; loop closure equations; the position of any point on a linkage; transmission angles and toggle positions; position-based synthesis of planar mechanisms. Velocity and acceleration analysis of Four-link and slider crank mechanisms using vector loop equations, coriolis component

Synthesis: Function generation, path generation, motion generation, Graphical Method**-** two-position and three-position synthesis of planar mechanisms, synthesis of quick return mechanisms, coupler curves, and exact and approximate straight-line mechanisms. Analytical linkage synthesis- two and three-position synthesis using vector loop equation, precision points, comparison of analytical and graphical synthesis methods.

Design of CAMS: Terminology and classification, double dwell cam design, svaj diagrams, combined functions, SCCA family, Polynomial Functions.

Robot Kinematics: Introduction to spatial descriptions and transformations, forward and inverse kinematics of manipulators

Learning Resources:

Text Books:

1. R L Norton, Kinematics and Dynamics of Machinery, McGraw Hill reprint 2016, 2nd Edition.

Reference Books:

1. John J. Craig, Introduction to robotics-Mechanisms and control, Pearson Education, Inc., 2005, 3rd edition,
2. Sandor and Erdman, Advanced Mechanism Design: Analysis and Synthesis, Vol II,PHI, New Delhi, 2010.

ME46025 **3-0-0 (3)**

THEORY OF PLATES AND SHELLS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Formulate Constitutive Relations and Equilibrium conditions applicable to plates
CO-2	Analyze the forces and bending moments in plates and shells
CO-3	Analyze Natural Frequencies and Modes in plates and shells under free vibrations
CO-4	Solve problems of Plates and Shells on Elastic Foundations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2		3			
CO-2	3	2	3	2	3	2
CO-3	3	2	3	2	3	
CO-4	3	2	3	2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Fundamental Relations, Equilibrium equations Kinematic Relations and Constitutive Relations.

Plate Theories: Thin plate concept, Kirchhoff-Differential Equation for studying the plates' stress strain, moments force, Variational Formulation, Boundary conditions: Fixed edges, clamped edges, simply supported plates with various load conditions (Analytical concepts) and mixed boundary conditions. Thick plate concepts, Reissner-Mindlin–Differential Equation, Finite Element/variational formulations for plate bending studies, Potential energy method for plate analysis.

Deep Shell Equations: Introduction, Shell Coordinates and Infinitesimal Distances in Shell Layers, Stress–Strain Relationships, Membrane Forces and Bending Moments, Energy Expressions, Boundary Conditions, Hamilton's Principle, Other Deep Shell Theories.

Natural Frequencies and Modes: General Approach, Rectangular Plates that are simply supported Along Two Opposing Edges, Circular Plates Vibrating Transversely, In-Plane Vibrations of Rectangular Plates.

Vibration of Shells and Membranes under the Influence of Initial Stresses: Strain-Displacement Relationships, Equations of Motion, Pure Membranes, Equations of Motion for Shells on Elastic Foundations, Plates on Elastic Foundations.

Learning Resources:

Text Books:

1. Werner. S, Vibration of Shells and Plates, Marcel Publishing House, 2004.
2. Ansel C Ugural, Stresses in Beams, Plates, and Shells, CRC Press, 2009, Third Edition.
3. Rudolph Szilard, Theories and Applications of Plate Analysis, John Wiley Publisher, 2004

Reference Books:

1. Saouma. V.E, Finite Element II Solid Mechanics, Springer, 2001.
2. S Timoshenko, Theory of Plates and Shells, Mc Graw Hill, 2017, 2nd edition.

Other Suggested Readings:

1. https://nptel.ac.in/noc/courses/noc18/SEM2/noc18-me65/

ME46027 **3-0-0 (3)**

MATHEMATICAL METHODS IN ENGINEERING

Pre-Requisites: **None**

Course Outcomes:

CO-1	Extend the methods of Applied Linear Algebra to engineering design problems
CO-2	Solve problems involving Nonlinear Optimization in engineering
CO-3	Simulate engineering systems using Numerical Methods.
CO-4	Model physical systems using Differential Equations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	3	1	2
CO-2	2	2	3	3	2	2
CO-3	3		3	3	3	2
CO-4	3		3	3	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Solution of Systems of Linear Equations: Introduction, Basic Ideas of Applied Linear Algebra, Systems of Linear Equations, Square, Non-Singular Systems, ILL-Conditioned and ILL-Posed Systems.

The Algebraic Eigenvalue Problem: The Algebraic Eigenvalue Problem, Canonical Forms, Symmetric Matrices, Methods of Plane Rotations, Householder Method, Tridiagonal Matrices, QR Decomposition, General Matrices.

Selected Topics in Linear Algebra and Calculus: Singular Value Decomposition, Vector Space: Concepts, Multivariate Calculus, Vector Calculus in Geometry, Vector Calculus in Physics.

An Introductory Outline of Optimization Techniques: Solution of Equations, Introduction to Optimization, Multivariate Optimization, Constrained Optimization: Optimality Criteria, Constrained Optimization: Further Issues.

Selected Topics in Numerical Analysis: Interpolation, Regression, Numerical Integration, Numerical Solution of ODE's as IVP Boundary Value Problems, Question of Stability in IVP Solution, Stiff Differential Equations, Existence and Uniqueness Theory.

Ordinary Differential Equations: Theory of First Order ODE's, Linear Second Order ODE's, Methods of Linear ODE's, ODE Systems, Stability of Dynamic Systems.

Application of ODE's in Approximation Theory: Series Solutions and Special Functions, Sturm-Liouville Theory, Approximation Theory and Fourier Series, Fourier Integral to Fourier Transform, Minimax Approximation.

Overviews: PDE's, Complex Analysis and Variational Calculus: Separation of Variables in PDE's, Hyperbolic Equations, Parabolic and Elliptic Equations, Membrane Equation, Analytic Functions, Integration of Complex Functions, Singularities and Residues, Calculus of Variations.

Learning Resources:

Text Books:

1. B. Dasgupta, Applied Mathematical Methods, Pearson Education, 2006.
2. E. Kreyszig , Advanced Engineering Mathematics, Wiley, 2010.

Reference Books:

1. M. T. Heath, Scientific Computing, McGraw-Hill Education, 2001.
2. Steven Chapra, Applied Numerical Methods with Matlab, McGraw-Hill Education, 2011.

ME46029 **3-0-0 (3)**

MECHANICS OF COMPOSITE MATERIALS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the characteristics of composite materials.
CO-2	Select suitable manufacturing processes to develop fiber reinforced composites.
CO-3	Analyze the micro and macro mechanical behavior of fiber reinforced composites.
CO-4	Develop the governing equations for bending, buckling and vibration of laminated plates.
CO-5	Design the composite structures for engineering applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1						2
CO-2	1					2
CO-3	1		3		2	
CO-4	2		3		2	2
CO-5	3		3		2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to composite materials: Classification and characteristics of composite materials, Mechanical behavior of composite materials, Basic terminology of laminated fiber reinforced composite materials, Manufacturing of laminated fiber reinforced composite materials.

Techniques for composites manufacturing: Hand laminating (or Wet Lay-up) and the Autoclave processing of composites, Filament winding and fiber placement, Pultrusion, Liquid composite molding.

Micromechanical behavior of lamina: Stress-strain relation for anisotropic materials, Stiffness, Compliances, Engineering constants, Restriction on Engineering constants, Stress-strain relation for plane stress in orthotropic materials.

Macro mechanical behavior of laminates and plate theories: Elastic approach to stiffness, Mechanics of materials approach to stiffness, Mechanics of materials approach to strength, Classical laminate theory, Special cases of laminate stiffness, Strength of laminates, Inter laminar stresses, Axisymmetric shells.

Bending, Buckling, and Vibration of Laminated Composites: Governing equations for Bending, Buckling, and Vibration of laminated plates, Deflection of simply supported laminated composites.

Learning Resources:

Text Books:

1. Ronald F. Gibson, Principles of composite material mechanics, CRC Press, 2011.

Reference Books:

1. Robert M Jones, Mechanics of Composite Materials, Taylor & Francis, 2000.
2. Lawrence E. Nielsen, Nielson, Paul Nielsen, Mechanical Properties of Polymers and Composites, Second Edition, CRC press, 2000.

ME46031 **3-0-0 (3)**

AUTOMATIC CONTROLS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze electromechanical systems by mathematical modelling.
CO-2	Determine Transient and Steady State behavior of systems using standard test signals.
CO-3	Analyze linear systems for steady state errors, absolute stability and relative stability using time domain and frequency domain techniques.
CO-4	Identify and design a control system satisfying specified requirements.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	2	2	
CO-2	3	3	3	2	2	
CO-3	3	3	3	2	2	
CO-4	3	3	3	2	2	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: System, control system, types of control systems, open-loop and closed loop systems, types of feedback, feedback and its effects. Concept of linearization with incremental changes.

Mathematical Modelling Of Physical Systems: Mathematical modelling of Electrical, Mechanical and Electro-mechanical elements, D.C. motors, flapper amplifiers, pneumatic amplifiers. Block diagram representation. Concept and use of Transfer function.

Transfer Function From Block Diagrams And Signal Flow Graphs: Introduction, impulse response and its relation with transfer function of linear systems. Block diagram reduction technique and signal flow graph, Mason's gain formula.

State Variable Analysis Of Linear Dynamic Systems: State variables, state variable representation of system, dynamic equations, merits for higher order differential equations and solution. Concept of controllability and observability and techniques to test them.

Time Domain Analysis Of Control Systems: Introduction- typical Test signals, time domain indices, steady state error constants, concept of BIBO stability, absolute stability, Routh Hurwitz Criterion. Effect of P, PI & PID controllers.

Root Locus Techniques: Introduction, Root loci theory, Application to system stability studies. Illustration of the effect of addition of a zero and a pole.

Frequency Domain Analysis Of Control Systems: Introduction, polar plots, Nyquist stability criterion, Frequency domain indices (gain margin, phase margin, bandwidth), Bode plots, application of Bode plots, Introduction to lag and lead compensation.

Qualitative Analysis Of Controllers: Introduction, Additions of Poles and Zeros, compensation – Phase Lag, Phase lead, feedback compensation, introduction to state space analysis – generalized state equation, techniques for deriving system state-space equations

Control Applications: Active vibration control – Principle of active control, structural vibration control, Active vibration isolation system, Engine Governing – Mechanical governors, Electronic governors, carburetor control, Diesel fuel Ignition control, Boiler control – combustion control, feed water control, steam temperature control.

Learning Resources:

Text Books:

1. Benjamin C Kuo and Golnaraghi, Automatic Control Systems, Mc Graw Hill, 2017, 10th Edition.
2. J. Nagarath, M. Gopal, Control Systems Engineering, New Age Pub. Co, 2017 6th Edition.

Reference Books:

1. Francis Harvey Raven, Automatic control engineering, McGraw-Hill, 2008.
2. Katsuhiko Ogata, Modern Control Engineering, Pearson Education India, 2015, 5th Edition.
3. B. C. Nakra and S. P. Singh, Theory and Application of Automatic Controls, New Age International Publishers., 2017, 3rd Edition.
4. C Sujatha, Vibration and Acoustics, Tata McGraw Hill, 2017

ME46033 **2-0-2 (3)**

Systems Thinking for Engineering Applications

Pre-Requisites: None — Basic engineering background is sufficient.

Course Outcomes:

CO1	Understand and explain the fundamental concepts of systems thinking — system boundaries, stocks, flows, feedback loops, delays, and non-linearity — in the context of mechanical engineering systems.
CO2	Construct and interpret Causal Loop Diagrams (CLDs) and Stock-and-Flow (SF) models to represent the dynamic behaviour of thermal, manufacturing, design, and automobile engineering systems.
CO3	Analyse system archetypes, feedback structures, and systemic failure modes to diagnose leverage points and unintended consequences in complex engineering problems.
CO4	Evaluate dynamic system behaviour including oscillations, overshoot, collapse, and growth using qualitative and introductory quantitative system dynamics modelling tools.
CO5	Design systemic interventions for complex real-world engineering problems by integrating systems thinking principles with sustainability, resilience, and sociotechnical considerations.

CO-PO Correlation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	1	1	2
CO2	**3**	2	**3**	**3**	**3**	1
CO3	**3**	2	**3**	2	2	2
CO4	**3**	2	**3**	**3**	**3**	1
CO5	**3**	**3**	2	2	2	**3**

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Detailed Syllabus:

Foundations of Systems Thinking: Why reductionist thinking fails for complex engineering problems; what is a system; system boundary, elements, interconnections, and purpose; open vs closed systems; stocks and flows — the building blocks of dynamic systems; Little's Law; feedback loops — reinforcing and balancing; delays; non-linearity and limits to growth; system traps; mental models and bounded rationality; case studies.

System Archetypes and Feedback Dynamics: Introduction to system archetypes — eight classic patterns (Senge, 1990); Archetypes 1–4: Limits to Growth, Shifting the Burden, Fixes that Fail, Tragedy of the Commons; Archetypes 5–8: Escalation, Eroding Goals, Growth and Underinvestment, Accidental Adversaries; oscillation and instability in feedback systems; archetype case studies across ME domains.

Causal Loop Diagrams and Stock-Flow Modelling: CLD notation, polarity conventions, loop identification and labelling; CLD construction; Systems Mapping methods — participatory causal mapping; comparing and combining CLDs with other causal mapping approaches (Barbrook-Johnson and Penn,

2022); Stock-and-Flow diagram notation; constructing SF models; rate and level equations; introduction to Vensim PLE software; simulation of reference mode behaviour; model validation and testing; sensitivity analysis; group modelling exercise.

Systems Thinking in Mechanical Engineering Domains: Systems Thinking in Thermal Engineering — CLD and case study: combined cycle power plant; Systems Thinking in Manufacturing Engineering — production system as a stock-flow network; Systems Thinking in Design Engineering — product development rework loops and schedule dynamics; Systems Thinking in Automobile Engineering — vehicle programme delay; cross-domain integration.

Complexity, Leverage, Sustainability and Systemic Design: Leverage points — Meadows' 12 places to intervene in a system; Complex Adaptive Systems; resilience and sustainability through a systems lens; Sociotechnical systems and transition dynamics; systemic design methodology; capstone project reviews — systems model and intervention recommendation presentations.

Experiential Practice and Capstone Project Work:

Student teams construct a complete Causal Loop Diagram and Stock-and-Flow model for a real engineering problem from their specialisation, identify leverage points using Meadows' hierarchy, and present a systems-aware intervention recommendation with sustainability implications. Vensim PLE software is used for simulation.

Learning Resources:

Text Books :

1. Donella H. Meadows (Ed. Diana Wright), Thinking in Systems: A Primer, Chelsea Green Publishing, 2008.

2. John D. Sterman, Business Dynamics: Systems Thinking and Modeling for a Complex World, McGraw-Hill/Irwin, 2000.

Reference Books:

1. Peter M. Senge, The Fifth Discipline: The Art and Practice of the Learning Organization, Updated Edition, Doubleday/Currency, New York, 2006.

2. Pete Barbrook-Johnson and Alexandra S. Penn, Systems Mapping: How to Build and Use Causal Models of Systems, Palgrave Macmillan, 2022. [Open Access — full PDF freely available at link.springer.com]

3. Brian C. Dangerfield (Ed.), System Dynamics: Theory and Applications, Springer, New York, 2020.

4. David Peter Stroh, Systems Thinking for Social Change: A Practical Guide to Solving Complex Problems, Chelsea Green Publishing, 2015.

ME46022 **3-0-0 (3)**

AI/ML FOR ENGINEERING ANALYSIS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the principles of statistics for Machine learning/deep learning
CO-2	Explore various supervised and unsupervised techniques for Machine learning and Deep learning
CO-3	Learn the programming skills for applying to ML/DL algorithms
CO-4	Apply the above skills to solve design and analysis problems
CO-5	Synthesize cams and followers for specified motion profiles

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1					2	2
CO-2	2		2		2	2
CO-3			3		3	3
CO-4	2				3	3
CO-5	3		3		3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Basics of Engineering Design and Statistics: Introduction to Statistics – descriptive statistics, dispersion measures, central tendency measures, hypothesis testing, inferential statistics, correlation and regression, p-value, central limit theorem, feature engineering

Machine Learning Algorithms: Basics of AI, ML, & DL. Fundamentals of ML - supervised, unsupervised, reinforcement learning. Supervised machine learning – Regression: linear regression, multilinear regression, non-linear regression, logistic regression. Classification: neural networks, decision trees, random forests, support vector machine, k-nearest neighbor. Unsupervised machine learning – mixture models, hierarchical k-means clustering, principal component analysis

Deep learning Algorithms: Deep feedforward neural nets, Convolutional neural networks, Long short-term memory (LSTM) networks. Introduction to Graph Neural networks, Generative Adversarial Networks, and Reinforcement Learning

Python for Machine Learning: Getting started with Python, Basic Commands, working with Python libraries, Loops, Variables, Data types, and Data visualization, exploring AI through python- neural networks and machine learning in python.

Applications: SHM Paradigm, feature extraction, feature importance, correlation, and eigenvalue analyses, feature augmentation, performance and validation of ML/DL models in mechanical engineering applications

Learning Resources:

Text Books:

1. Thomas Nield, Essential math for data science, Oreilly, June 2022

Reference Books:

1. Marc peter, Aldo Faisal, Cheng soon, Mathematics for Machine learning, Cambridge, 2021

ME46024 **3-0-0 (3)**

CONDITION MONITORING AND FAULT DIAGNOSTICS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand effective maintenance schemes in industries.
CO-2	Apply vibration monitoring techniques for system diagnoses.
CO-3	Apply oil analysis technique to diagnose the wear debris.
CO-4	Identify nonconventional methods for machine diagnoses.
CO-5	Develop modern technologies for effective plant maintenance.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1					2	3
CO-2	3		3		2	
CO-3	3		3		2	
CO-4	3		3		2	
CO-5	3		3		2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Vibration based condition monitoring: Introduction, Type of failures, investigation and occurrences, Service failures, Principles of predictive maintenance, Predictive maintenance techniques, sensors for fault detection, Vibration transducers, Vibration basics, Spring-mass system: mass, stiffness, damping, System response, Nature of vibration, Harmonics, Limits and standards of vibration.

Data acquisition and analysis: Introduction, Vibration sensors, characteristics and mountings Collection of vibration signal, Vibration signature of active systems, Vibration monitoring equipment, Critical vibration levels, Conversion of vibrations to electrical signal, The fast Fourier transform (FFT) analysis, Frequency analysis techniques, Derived functions, Time waveform analysis, Phase signal analysis.

Machinery fault diagnosis and correcting faults: Introduction, Commonly witnessed machinery faults diagnosed, Simple vibration, Belt drives, Gear excitation, Rolling elements bearing, Balancing, Alignment, Resonance vibration control with dynamic absorbers.

Wear debris analysis: Introduction, Oil fundamentals, sampling methods, lubricant properties, Contaminants in used lubricating oils, Contaminants monitoring techniques, Spectrometric oil analysis, Magnetic chip detectors, Ferrograph particle precipitation, XRF, Temperature analysis.

Other predictive maintenance techniques: Performance trend monitoring, Performance monitoring systems, Introduction to non-destructive techniques, Ultrasound, Infrared thermography, Eddy current, Introduction to structural health monitoring

Learning Resources:

Text Books:

1. Rao J. S., Vibration Condition Monitoring, Narosa Publishing House, 2000, 2nd edition.
2. Isermann R., Fault Diagnosis Application, Springer-Verlag Berlin, 2011

Reference Books:

1. Allan Davis, Hand book of Condition Monitoring, Chapman and Hall, 2000.
2. Choudary K K., Instrumentation, Measurement and Analysis, Tata McGraw Hill.
3. Collacott, R. A., Mechanical Faults Diagnosis, Chapman and Hall, London, 1990
4. Vibration and Acoustics, C Sujatha, Tata McGraw Hill, 2017

ME46026 **3-0-0 (3)**

FRACTURE MECHANICS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the concept of crack subsequently leading to fracture failure Further analyze the mechanical components against fracture.
CO-2	Analyze and predict the fracture strength of mechanical components under different fracture modes.
CO-3	Application of fracture mechanics principles by Determining Fracture Parameters using Experimental Methods.
CO-4	Designing of mechanical components against fracture by Determining Fracture Parameters for the analysis of cracks in solids.
CO-5	Analyze the mechanical components against fracture by Detection of crack and its growth through Non-Destructive Testing.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3	2	2
CO-2	3	3	3	2	2	2
CO-3	3	3	2	2	3	2
CO-4	3	3	3	3	3	2
CO-5	2	2	3	3	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Brittle and Ductile Fracture, Modes of Fracture Failure, Surface Energy, Griffith's Dilemma, Realization and Analysis. Energy Release Rate, Energy Release Rate of DCB Specimen, Anelastic Deformation at Crack-tip, Crack Resistance, Stable and Unstable Crack Growth, Critical Energy Release Rate.

Stress Intensity Factor: Linear Elastic Fracture Mechanics (LEFM), Westergaard's Approach, Applications of Westergaard Approach, Crack in a Plate of Finite Dimensions, Edge Cracks, Embedded Cracks, The Relation between G_I and K_I , Critical Stress Intensity Factor, Bending and Twisting of Cracked Plates. Approximate Shape and Size of the Plastic Zone, Effective Crack Length, Effect of Plate Thickness.

J-Integral: Definition of the J-Integral, Path Independence, Stress-Strain Relation, Experiments to Determine the CriticalJ-Integral, Comments on the Numerical Evaluation ofJ-Integral, A Simplified Relation for the J-Integral, Applications to Engineering Problems. Crack Tip Opening Displacement, Relationship between CTOD, Kr and Gr for Small Scale Yielding, Equivalence between CTOD and J.

Test Methods: K_{IC}-Test Technique, Test Methods to Determine J_{IC} , Test Methods to Determine G_{IC} and G_{IIC} , Determination of Critical CTOD.

Fracture Parameters: Direct Methods to Determine Fracture Parameters. Indirect Methods to Determine Fracture Parameters. Mixed Mode Crack Initiation and Growth.

Crack Detection through Non-Destructive Testing: Examination through Human Senses, Liquid Penetration Inspection, Ultrasonic Testing, Radiographic Imaging, Magnetic Particle Inspection.

Learning Resources:

Text Books:

1. Prashant Kumar, Elements of fracture mechanics, Tata McGraw-Hill Education, 2009.

2. Anderson, Ted L., Fracture mechanics: fundamentals and applications. CRC press, 2017.

Reference Books:

1. Broek, David, Elementary engineering fracture mechanics, Springer Science & Business Media, 2012.
2. S.T. Rolfe and J.M. Barson, Fracture and Fatigue control in Structures, Prentice Hall Inc. New Jersey, 1977.
3. M.F. Kanninen and C.H. Popelar, Advanced Fracture Mechanics, Oxford University Press, 1985

ME46028 **3-0-0 (3)**

OPTIMIZATION METHODS FOR ENGINEERING DESIGN

Pre-Requisites: **None**

Course Outcomes:

CO-1	Formulate a design task as an optimization problem.
CO-2	Solve unconstrained optimization problems using corresponding methods.
CO-3	Solve unconstrained optimization problems using corresponding methods.
CO-4	Solve the nonlinear optimization problems with evolutionary methods

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	3	1	2
CO-2	2	2	3	3	2	2
CO-3	3		3	3	3	2
CO-4	3		3	3	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Optimization in Design: Problem formulation, Optimization problems in Mechanical Engineering, Classification of methods for optimization

Single-variable Optimization: Optimal criteria, Derivative-free methods (bracketing, region elimination), Derivative based methods, root-finding methods.

Multiple-variable Unconstrained Optimization: Optimal criteria, Direct search methods (Box's, Simplex, Hooke-Jeeves, Conjugate methods), Gradient-based methods (Steepest Descent, Newton's, Marquardt's, DFP method). Formulation and Case studies.

Constrained Optimization: KKT conditions, Penalty method, Sensitivity analysis, Direct search and gradient based methods for constrained optimization. Formulation and Case studies.

Evolutionary Optimization algorithms: Philosophy**,** Genetic algorithms and simulated annealing.

Multi-objective Optimization: Terminology and concepts, the concepts of Pareto optimality and Pareto optimal set, formulation of multi-objective optimization problem, NSGA.

Case studies and Computer Implementation: Representative case studies for important methods and development of computer code for the same to solve problems.

Learning Resources:

Text Books:

1. Jasbir Arora, Introduction to Optimum Design, Academic Press, 2004.

Reference Books:

1. Kalyanmoy Deb, Optimization For Engineering Design: Algorithms and Examples, PHI, 2004.
2. Kalyanmoy Deb, Multi-Objective Optimization using Evolutionary Algorithms, Wiley, 2001

ME46030 **3-0-0 (3)**

ROBOTICS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify robots based on joints and arm configurations.
CO-2	Design application specific End Effectors for robots.
CO-3	Compute forward and inverse kinematics of robots and determine trajectory plan.
CO-4	Program robot to perform typical tasks including Pick and Place, Stacking and Welding
CO-5	Design and select robots for Industrial and Non-Industrial applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1			2	2	3	2
CO-2	2		3	2	3	2
CO-3	2		2	2	2	2
CO-4	2		2	2	2	2
CO-5	3	1	3	3	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Multibody systems, Automation, Classification of robots, Anatomy, Sensors (velocity, proximity, touch, torque etc), Grippers, selection of Robot based on the Application. Demonstration of different types of Robots & tools using Robot Simulator Software like ROBODK.

Kinematics: Manipulators Kinematics, Rotation Matrix, Homogenous TransformationMatrix, Direct and Inverse Kinematics for industrial robots for Position and orientation. Demonstrate FK and IK using simulation tools.

Differential Kinematics, statics and Dynamics: Jacobian, Lagrangian Formulation, Newton-Euler Formulation for RR & RP Manipulators. Demonstrate differential kinematics using simulation tools.

Trajectory planning & Control: Motion Control- Interaction control, Rigid Body mechanics, Control architecture- position, path velocity and force control systems, computed torque control, adaptive control, and Servo system for robot control. Demonstrate trajectory planning using simulation tools.

Advanced Topics in Robotics: Motion Planning (Methods of Path planners), Robot Vision (Feature Detection & Matching, Motion Tracking, Machine Learning methods).

Programming of Robots: Overview of various programming languages.

Application of Robots in production systems: Application of robot in welding, machine tools, material handling, and assembly operations parts sorting and parts inspection.

Learning Resources:

Text Books:

1. Fu, K.S., Gonzalez, R.C., and Lee, C.S.G., Robotics control, Sensing, Vision and Intelligence, McGraw-Hill Publishing company, New Delhi, 2003.

Reference Books:

1. Klafter, R.D., Chmielewski, T.A., and Negin. M, Robot Engineering: An Integrated Approach, Prentice Hall of India, New Delhi, 2002.
2. Craig, J.J., Introduction to Robotics Mechanics and Control, Addison Wesley,1999.
3. Kevin M. Lynch, Frank C. Park, Modern Robotics: Mechanics, Planning, and Control, Cambridge University Press, 2017

ME46032 **3-0-0 (3)**

ROTOR DYNAMICS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Model the Rotor bearing systems and formulate the governing equations.
CO-2	Understand the role of damping, gyroscopic, centrifugal, stiffness and inertialeffects on rotors.
CO-3	Compute the critical speeds and stability limits for rotors under axial, transverseand torsional modes.
CO-4	Analyse the rotor bearing systems using transfer matrix method and FiniteElement Method.
CO-5	Compute the transient response of rotors.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3		3		3	2
CO-2	2		3			2
CO-3	3		3	2	3	2
CO-4	3		3	2	3	2
CO-5	2		3		3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction to rotor dynamics, Rotating and reciprocating unbalances, Classification of Discrete and continuous systems, Review of free and forced vibrations of single and multi-degree of freedom systems.

Linear Rotor Dynamics : Equation of motion, Rotating systems, Complex coordinate representation, Undamped Jeffcott Rotor – Free whirling, Unbalance response, Shaft Bow Jeffcott Rotor with viscous damping – Free whirling, Unbalance response, Shaft Bow With structural damping – Free whirling, Unbalance response, frequency dependent loss factors with non-synchronous damping, Effect of Bearing Compliance,Stability in supercritical region.

Modelling with Four Degrees of Freedom: Generalised coordinates and equations of motion in real and complex coordinates, Static and couple unbalance and their effects, uncoupled gyroscopic systems, Free whirling of coupled undamped systems, Unbalance response and Shaft bow. Model uncoupling of gyroscopic systems, Configuration and state space approaches.

Discrete multi-degree of freedom: Introduction, Transfer matrix approach for undamped systems, Damped systems, The finite element method for rotors, Beam elements, spring elements, Mass elements, Assembly and constraints, Damping matrices, Choice of coordinates: fixed Vs Rotating and Real Vs Complex coordinates, Computation of critical speeds, Computation of unbalance response. Campbell and root locus diagrams, Reduction of DOF: Nodal reduction, model reduction and component mode synthesis.

Transmission Shafts: Modelling of rotors as continuous systems, Euler-Bernoulli and Timoshenko beam models, Dynamic stiffness, Analytical and approximate solutions.

Anisotropy of rotors and supports: Isotropic rotors on Anisotropic supports – Influence of damping, non-isotropic rotors on isotropic supports.

Rotor-Bearing Interaction: Rigid body and flexural modes, Linearization of bearing Characteristics, Rolling element bearings, Fluid film bearings, Magnetic bearings, bearing alignment in multi rotor bearings

Learning Resources:

Text Books:

1. Giancarlo Genta, Dynamics of Rotating Systems, Springer, 2009
2. Rao, J.S., Rotor Dynamics, New Age International, 2003, 3 Edition.

Reference Books:

1. Chong-Won Lee, Vibration Analysis of Rotors, Kluwer Academic Publishers, London, 1995
2. Muszynska A, Rotor dynamics, Taylor & Francis, New York, 2005

ME46034 **3-0-0 (3)**

TRIBOLOGY IN DESIGN

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze properties of lubricant and select proper lubricant for a given application.
CO-2	Identify tribological performance parameters of sliding contact in different lubrication regimes.
CO-3	Design and select appropriate bearings for a given application
CO-4	Predict the type of wear and volume of wear in metallic and polymer surfaces

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	2		2
CO-2	3	3	3	3	2	
CO-3	3	2	3	2	3	2
CO-4	3		3	2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Overview of the course, history and basic concept of friction, wear and lubrication.

Lubricants: Types of lubricants, Objectives of lubricant, Physical properties of lubricants, Selection of lubricant.

Lubrication modes and Theories of lubrication: Modes of lubrication - hydrodynamic, hydrostatic, Elasto-hydrodynamic, mixed and boundary lubrication, Reynolds' equation, Applications of hydrodynamic lubrication theory - Journal bearing and Inclined thrust pad bearing, Hydrodynamic lubrication of roughened surfaces, Theories of Externally pressurized lubrication, Squeeze-film lubrication, Elasto-hydrodynamic lubrication and air lubricated bearing.

Lubrication regimes and bearings design: Rheological lubrication regime, Functional lubrication regime, Bearing types and its selection. Bearings design.

Friction and Wear: Origin of sliding friction, Contact between two bodies in relative motion, Types of wear and their mechanisms - Adhesive wear, Abrasive wear, Wear due to surface fatigue and wear due to chemical reactions, wear of metallic materials, Tribology of polymers.

Special topics: Bio-tribology, Introduction to MEMS, Nano Tribology and Space Tribology

Learning Resources:

Text Books:

1. Stachowaik, G.W., Batchelor, A.W., Engineering Tribology, Elsevier, 2010, 3rd Edition.
2. Majumdar B.C, Introduction to bearings, S. Chand & Co., Wheeler publishing, 1999.
3. Andras Z. Szeri, Fluid film lubrication theory and design, Cambridge University press, 1998..

Reference Books:

1. TA Stolarski, Tribology in Machine Design, Butterworth-Heinemann, 2000.
2. Williams JA, Engineering Tribology, Oxford Univ. Press, 2001.
3. Cameron A, Basic lubrication theory, Ellis Horwood Ltd., 2002.
4. Neale MJ, Tribology Hand Book, CBS Publications, 2012.
5. Harish Hirani, Fundamentals of Engineering Tribology with Applications, Cambridge University press, 2016.

ME46036 **3-0-0 (3)**

CHARACTERIZATION OF ENGINEERING MATERIALS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify advanced techniques available for characterization of materials
CO-2	Select a characterization technique to evaluate the behavior of materials
CO-3	Analyze defects and failure surfaces of materials
CO-4	Analyze the characterization results by various equipment

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	2	3	3
CO-2	3	2	2	2	2	2
CO-3	3	3		3		2
CO-4	3	3	2	2	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Overview of the course; materials classification and their properties, Importance of materials selection, property classification, Criteria for selection of materials, Ashby charts for materials selection, Engineering Design process and the role of materials; material property charts; selection of materials based on function, objective, constraints and free variables; examples of material selection for typical applications.

Computer aided materials selection: Selection of process based on material classification; pencil curve approach; material selection for multiple constraints and multiple objective cases; multiple constraints and conflicting objectives. Co-selection of material and shape; concept of macroscopic and microscopic shape factors; Four quadrant method of material selection. General Properties of plastics, polymers and elastomers; visco-elastic properties; short-term and long-term properties of plastics.

High temperature materials: families of super alloys and their characteristics; creep and fatigue resistance of super alloys; role of precipitates in strengthening of super alloys; repair of super alloys after creep damage; coatings for high temperature materials.

Fundamentals of ceramics: general properties, applications of ceramics for critical applications. Design considerations. Surface treatment of materials using coatings; type of coatings; PVD and CVD coatings. Basics of electro-plating and electro-less plating.

Physical characterization of materials: Optical Microscopy, SEM,TEM, Density, Void content in materials, Electron Probe Micro Analyzer (EPMA), Atomic Force Microscopy (AFM), Thermogravimetric analysis (TGA), nano indentation, NMR spectroscopy, EDAX, FTIR, XRD

Mechanical characterization: Tensile test, flexural test, compression test, ILSS, creep, fatigue, Hardness, Impact test, Fracture toughness test, Principle, construction and operation working parameters, equipment operation. selection of plastics based on mechanical properties, degradation due to environment, of laminates.

Tribological characterization: Abrasive wear, Pin-on Disc, Erosion test, Corrosion test, sand abrasion, slurry erosion, scratch test, nano indent scratch test, wear; Design methods for snap fits; case studies. Fundamentals of fiber reinforced plastics; Stress, strain analysis of continuous fiber composites, rule of mixtures, general deformation behavior

Learning Resources:

Text Books:

1. M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Heinemann, 2010, 4th edition.

2. Yang Leng, Materials Characterization-Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia) Pte Ltd, 2008.
3. Dieter,George E, Mechanical Metallurgy, McGraw Hill, 2nd Edition, 2005

Reference Books:

1. ASM Handbook: Materials Characterization, ASM International, 2008.
2. V. T. Cherapin and A. K. Mallik, Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.
3. Crawford, R. J., Plastics Engineering, Butterworth-Heinemann, 3/e, 2002.
4. Donachie, M. J. and Donachie, S. J., Super alloys: A technical guide, ASM International, 2002.

ME46038 **3-0-0 (3)**

SMART MATERIALS AND SENSORS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify smart materials based on the engineering applications
CO-2	Develop constitutive equations and mathematical models for the smart materials
CO-3	Design sensing devices and structures using smart materials
CO-4	Adapt smart sensors for measurement of physical properties and structural health monitoring

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2		3			
CO-2	3	2	3	2	3	2
CO-3	3	2	3	2	3	
CO-4	3	2	3	2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction of smart materials- Piezoelectric materials, magneto-strictive materials and magneto-resistance effect, electroactive materials and polymers, Shape memory alloys and polymers, electro and magneto rheological fluids, intelligent materials.

Piezoelectric Materials: Piezoelectric effect, Constitutive equations, properties of piezoelectric materials, variation of coupling coefficients for PZT materials, Mathematical modelling- Electro mechanical performance.

Magneto-strictive Materials and Shape memory alloys: Magneto-strictive Sensing Magneto mechanical coupling coefficients of magneto-strictive materials, constitutive relationships, Villari Effect, Matteuci Effect and Nagoka-Honda Effect, Magnetic Delay Line Sensing, Magneto strictive mini actuators. Classification of shape memory alloys, methods of fabrication, Control design for shape memory alloys and polymers, Electroactive polymers and its applications, LBHS and HBLS smart actuators.

Smart sensors: Selection of sensors and its monitoring techniques for monitoring force, position, vibration, noise, temperature for the mechanical systems-Integrated and distributed temperature sensing, strain measurements, fluid rheological properties measurements using FBG and ultrasonic sensors, Application of accelerometers, EAP, SMAs, vision sensors, MEMS based actuators, robot sensors, micro sensors, Nano sensors, Case studies and student presentations

Structural Health Monitoring using Smart Sensors: Structural integrity using fiber optic, acoustic/ultrasonic, and piezoelectric active sensors/patches, piezoelectric smart structures-numerical and experimental methods. Delamination sensing using magneto-strictive and Piezoelectric sensors. Case studies and student presentations.

Learning Resources:

Text Books:

1. Victor Giurgiutiu, Structural Health monitoring with Piezoelectric Wafer Active sensors, Academic Press, 2008, 1st edition
2. Thompson and Gandhi, Smart Materials and Structures, Chapman and Hall, 1992

Reference Books:

1. Alper Erturk and Daniel J Inmann, Piezoelectric energy harvesting, Wiley Publications, 2011, 1st edition
2. Krzysztof Iniewski, Smart sensors for industrial applications, CRC Press Taylor and Francis group, 2013.
3. Ananthasuresh, G. K., Vinoy, K. J., Gopalakrishnan, S., Bhat, K. N., and Aatre, V. K, Micro and Smart Systems: Technology and Modeling, Wiley, New York, 2012.

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/104/112104173/

ME46040 **3-0-0 (3)**

NOISE, VIBRATIONS AND HARSHNESS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic terminologies of Noise, Vibration, Harshness and Safety.
CO-2	Acquire Comprehensive, knowledge of Sources of Vibration and Noise applicable to the automobile engineering discipline and possibility of modifications and improvements.
CO-3	Apply engineering techniques, tools, for measurement methods in order to learn to control and solve complex Vehicle performance problems.
CO-4	Analyze the principles of safety of automobile under different road and environment and load condition.
CO-5	Design processes for eliminating or reducing the Vibration, Noise to reduce irritation to occupants and achieve improvement in perception of ride comfort.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3		2	2	2	1
CO-2	3		2	2	2	1
CO-3	3		2	2	2	1
CO-4	3		2	2	3	1
CO-5	3		2	3	3	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

NVH in the Automotive Industry: Sources of noise and vibration. Design features. Common problems. Marque values. Noise quality. Pass-by noise requirements. Target vehicles and objective targets. Development stages in a new vehicle programme and the altering role of NVH engineers.

Characteristics & Sources of Vibrations: Free and Forced Vibration, Natural Frequency, Un-Damped & Damped Vibrations, Unit Impulse, Vibration Isolation, Transmissibility. Power Train: Engine, Clutch, Transmission, Propeller shaft, 3 Differential, Drive shaft, Trans axle. Power train mounts.

Sources of Noise, Measurement Technics and Control: Noise specifications and mandatory standards regulations. Brake Squeal noise, Pass-by Noise, wind noise, squeak noise and rattle, interior noise (including noise emitted by running of accessories, indicators and all buzzers). Power train, Engine Air Intake & Exhaust noise, Engine accessories, cooling system and vehicle body protrusion noise, under body protrusion noise. Noise due to Tyre-Road friction and slip characteristics.

Noise Measuring Instruments: Microphone, Sound intensity probes. Noise Control: Damping treatment methods, Control through isolations and noise absorbing materials and structure. Active and semi-active control of noise. Study of anechoic chamber.

Signal Processing: Sampling, aliasing and resolution. Statistical analysis. Frequency analysis. Campbell's plots, cascade diagrams, coherence and correlation functions.

Harshness: Definition. Its effect and acceptable degree of Harshness. Perception of Ride comfort i.e. psychological effects of Noise & Vibrations. Study of NVH - Legislations applicable for vehicles in India.

Safety: Passive safety Active safety, Study of Safety Regulations for vehicular application.

Learning Resources:

Text Books:

1. Chen, G.S., Vehicle Noise Vibration and Sound Quality. SAE International, 2012,

2. D. G. Karczub, M.P Norton, Fundamentals of Noise and Vibration Analysis for Engineers by Cambridge University Press,2003, 2nd Edition
3. S.S.Rao , Mechanical Vibrations, Pearson, 2018, 6th Edition
4. W.T.Thomson & M.D.Dahleh, Theory of Vibration with Applications, by, Pearson Education,2008, 5th Edition.
5. J.K.Thompson, Brake NVH Testing and Measurements by, SAE International Publications,2011

Reference Books:

1. Baxa, Donald E.; Petska, Darrell E., Noise Control of Internal Combustion Engine, New York John Wiley and Sons, 1982, 1st Edition.
2. Munjal N.S, Acoustic Duct and Mufflers John Wiley Publications, 2nd Edition.
3. Vibrations and Noise for Engineers, Kewal Pujara, Dhanpat Rai & Co.,2018,
4. Rao V. Dukkipati and J. Srinivas; Text Book of Mechanical Vibrations, PHI, 2012, 2nd Edition

ME26030 **3-0-0 (3)**

PRODUCT LIFE CYCLE MANAGEMENT

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand product data, information, structures and PLM concepts.
CO-2	Apply PLM systems in organization verticals including production, after sales, sales and marketing, and subcontracting.
CO-3	Measure benefits of PLM implementation in daily operations, material costs, productivity of labour and quality costs.
CO-4	Apply PLM concepts for service industry and E-Business.
CO-5	Recognize tools and standards in PLM.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1			2	2	2	1
CO-2	2	2	3	2	3	2
CO-3	2		3	3	2	2
CO-4	2	2	3	3	3	2
CO-5	3		3	3	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Fundamentals of PLM: Product data or Product information, Product lifecycle management concept, Information models and product structures-Information model, The product information (data) model, The product model, Reasons for the deployment of PLM systems.

Enterprise solution with PLM: Use of product lifecycle management systems in different organization verticals, Product development and engineering, Impact of Manufacturing with PLM Challenges of product management in the engineering and manufacturing industry, Life cycle thinking, value added services and after sales, Case 1: Electronics manufacturer, Case 2: An engineering product.

Product Structures: Standardized product data and materials data model, Product structure of a ship, Product structure of a customizable product, Product structure of a configurable service product.

PLM service information model: Categorizing services , Rational for building service products, How to make a service more like a tangible product?, Making items out of product functions, PLM challenges in service business, An IT-service provider and a customer-specifically variable product.

PLM for e-manufacturing: electronic business and PLM, Preconditions for electric business from the viewpoint of the individual company, Significance of product management, collaboration and electronic business for the manufacturing industry.

Integration of the PLM system with other applications: Different ways to integrate PLM systems, Transfer file, Database integration, System roles, ERP, Optimization of ERP for PLM and CAD.

Implementing end to end business process management: Product lifecycle management as a business strategy tool, Product lifecycle management as an enabler of cooperation between companies, Contents of collaboration, Successful cooperation, Tools of collaboration, From changes in the business environment to product strategy, Business Benefits of PLM.

PLM applications in process and product industries examples: Case 1: Electronics manufacturer, Case 2: An engineering product, Case 3: Capital goods manufacturer and customer-specifically variable product, Case 4: An IT-service provider and a customer-specifically variable product.

Learning Resources:

Text Books:

1. Jaya Krishna S, Product Lifecycle Management: Concepts and cases, ICFAI Publications 2011

Reference Books:

1. SOA approach to Enterprise Integration for Product Lifecycle, IBM Red books, 2011.