M.Tech. Program from Department of Mechanical Engineering

M. Tech. in Mechanical Design

Semester wise detailed syllabus

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	HS5111	Technical Writing and Soft Skill	1	2	2	4
2.	ME5101	Advanced Engineering Mathematics	3	1	0	4
3.	ME5102	Theory of Elasticity	3	0	0	3
4.	ME5103	Finite Element Analysis	3	0	0	3
5.	ME5104	Design Lab - I	0	0	3	1.5
6.	ME61XX	DE-I	3	0	0	3
7.	ME61XX	DE-II	3	0	0	3
8.	XX61PQ	IDE	3	0	0	3
	TOTAL		**19**	**3**	**5**	**24.5**

Course Number	**ME5101**
Course Credit	L-T-P-C: 3-1-0-4
Course Title	**Advanced Engineering Mathematics**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1-4. • This course aims to train the students with the basic and advanced mathematical tools required to solve engineering problems. • Showcase the utility of mathematics towards the analysis of real-world engineering problems.
Course Description	This course is designed to fulfil the need for basic and advanced mathematics concepts often used in real-life engineering problems. Prerequisite: NIL
Course Outline	Linear Algebra: Matrix algebra; basis, dimension and fundamental subspaces; solvability of Ax = b by direct Methods; orthogonality and QR transformation; eigenvalues and eigenvectors, similarity transformation, singular value decomposition, Fourier series, Fourier Transformation, FFT. Vector Algebra & Calculus: Basic vector algebra; curves; grad, div, curl; line, surface and volume integral, Green's theorem, Stokes's theorem, Gauss-divergence theorem. Differential Equations: ODE: homogeneous and non-homogeneous equations, Wronskian, Laplace transform, series solutions, Frobenius method, Sturm-Liouville problems; PDE: separation of variables and solution by Fourier Series and Transformations, PDE with variable coefficient. Numerical Technique: Numerical integration and differentiation; Methods for solution of Initial Value Problems, finite difference methods for ODE and PDE; iterative methods: Jacobi, Gauss-Siedel, and successive over-relaxation. Complex Number Theory: Analytic function; Cauchy's integral theorem. Statistical Methods: Descriptive statistics and data analysis, correlation and regression, probability distribution.
Learning Outcome	• This course would enable the students to solve the mathematical governing equations of engineering problems**.** • The students would be able to realise the connection of Mathematics with Physics and Engineering.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment, Class Performance and Viva

Suggested Readings:

Text Books:

1. H. Kreyszig, "Advanced Engineering Mathematics", Wiley, (2006).
2. Gilbert Strang, "Linear Algebra and Its Applications", 4th edition, Thomson Brooks/Cole, India (2006).
3. J. W. Brown and R. V. Churchill, "Complex Variables and Applications", McGraw-Hill Companies, Inc., New York (2004).
4. J. W. Brown and R. V. Churchill, "Fourier Series and Boundary Value Problems", McGraw-Hill Companies, Inc., New York (2009).
5. G. F. Simmons, "Differential Equations with Applications and Historical Notes", Tata McGraw-Hill Edition, India (2003).
6. S. L. Ross, "Differential Equations" 3rd edition, John Wiley & Sons, Inc., India (2004).
7. K. S. Rao, "Introduction to Partial Differential Equations", PHI Learning Pvt. Ltd (2005).
8. R. Courant and F. John, "Introduction to Calculus and Analysis, Volume I and II", Springer-Verlag, New York, Inc. (1989).

9. K. Atkinson and W. Han, “Elementary Numerical Analysis” 3rd edition, John Wiley & Sons, Inc., India (2004).
10. R. A. Johnson and G. K. Bhattacharya, “Statistics, Principles and Methods”, Wiley (2008).
11. Michael D Greenberg, “Advanced Engineering Mathematics”, 2^{nd} Edition, Pearson (1998).
12. R.K. Jain and S. R. K. Iyengar, “Advanced Engineering Mathematics” 4^{th} Edition, Narosa; 1st Edition (2002).

Course Number	**ME5102**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Theory of Elasticity**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1 and 3. The analytical and mathematical concepts of elasticity and their applications in a wide range of engineering problems will be taught in this course.
Course Description	This course is designed to fulfil an understanding of theories of linear and non-linear elasticity, stress and strain tensors, equilibrium and compatibility equations, analytically and numerically solving elasticity problems, and the concept of energy principles and stress functions. **Prerequisite**: Knowledge of solid mechanics or equivalent course
Course Outline	Stress and strain tensors, equations of equilibrium and compatibility in rectangular and curvilinear coordinates, Cauchy's formula, stress transformation, principal stresses, Lame's stress ellipsoid, Cauchy stress quadratic, octahedral stress, stress-strain relations, basic equations of elasticity, Boundary value problem, Uniqueness of solutions, Torsion of non-circular sections, St. Venant's theory of torsion, Scalar and Vector potentials, Strain potentials. Plane state of stress and strain, Airy's stress function for problems, Representation of biharmonic function using complex variables, Kolosoff-Mushkelishvili method. Thermal stress, Applications to problems of curved beam, thick cylinder and rotating disc, stress concentration. Introduction to numerical methods in elasticity. Contact problems, Introduction to Viscoelasticity and plasticity, energy and variational principles in theory of elasticity.
Learning Outcome	• Understanding stress and strain tensors, equilibrium and compatibility equations, and concept of boundary conditions develop a mathematical foundation of elasticity theories. • Ability to solve linear and non-linear elasticity problems by analytical and numerical approaches. • Understanding the use of energy principles and stress functions in solving elasticity problems.
Assessment Method	Class tests, quizzes, projects (Case Studies), mid-semester and end semester Examinations.

Suggested Readings:

Text Books:

1. S.P. Timoshenko and J.N. Goodier, Theory of Elasticity, Tata McGraw-Hill, 2010.
2. L.S. Srinath, Advanced Solid Mechanics, Tata McGraw-Hill, 2002.
3. I.S. Sokolnikoff, Mathematical Theory of Elasticity, 2nd Ed., McGraw-Hill, 1956.
4. Y.C. Fung, Foundations of Solid Mechanics, Prentice-Hall, 1965.
5. Theory of Plasticity by Jagabanduhu Chakrabarty, Butterworth-Heinemann; 3rd edition, 2006.
6. Introduction to Computational Plasticity by Fionn Dunne and Nik Petrinic, OUP Oxford, 2005.

Course Number	**ME5103**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Finite Element Analysis**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLO 4 This course aims to provide the mathematical concepts and detailed algorithm of finite element method and its applications in wide range of engineering problems.
Course Description	This course on FEM discusses all the important topics starting from fundamentals and mathematical modeling of boundary value problems, initial value problem and Eigenvalue problems in one and two-dimensional domains. Formulations for different element such as constant strain triangles, parametric elements and numerical integration, beams and frames, linear static analysis, and Eigenvalue problems in one and two-dimensional domains. Formulations for different elements such as constant strain triangles, isoparametric elements and numerical integration, beams and frames, linear static analysis, Dynamic analysis, Thermal analysis, Buckling analysis, scalar field problems, pre-processing and post processing
Course Outline	**Basic Concepts**: Introduction, weak formulations, variational formulations, weighted residual method, Rayleigh-Ritz and Galerkin's method. **One Dimensional Problems**: Second-order differential equations in one dimension, Basis steps, discretization, assembly, local and global stiffness matrix and its properties, boundary conditions, multipoint constraints, applications to: solid mechanics heat transfer and fluid mechanics, Electromagnetic problems, axisymmetric problems **Trusses, Beams and Frames**: Plane truss, local and global coordinate systems, stress calculations, temperature effect on truss members, Euler Bernoulli beam element, C^0 and C^1 elements, Hermite cubic spline functions, frame element, Numerical examples, Case Studies. **Eigen Value and Time dependent problems**: Formulation, FEM models, semidiscrete FEM models, method and Newmark scheme, Applications, problems, convergence and accuracy, Numerical examples **Scalar Field Problems**: Single variables in 2-D, heat transfer, potential flow problems, Electromagnetic, impositions of BCs, Numerical examples. **Convergence and error:** Energy and L_2 norm, accuracy and error, stability **Two Dimensional Problems**: Constant strain triangle, isoparametric formulation, master elements, higher order elements, serendipity elements, hybrid element, quaterpoint element, modelling considerations, mesh generation, numerical integration, reduced integration, *computer implementation*: heat transfer in thin fins, 2D plane stress/plain strain. **Modelling considerations:** Element Geometries, Mesh Generation, Load representation, Discussion on Plane stress, plane strain, plate, membrane, Thin Shell elements **Post Processing Techniques:** Viewing of results, Average and unaverage stress, Interpretation of results. **Limitations with FEM:** Introduction of Meshfree Methods, XFEM, Phase Filed Modelling, Application

Learning Outcome	• Ability to mathematically formulate and ***solve*** Multiphysics problem: Solid, Thermal, Fluid, etc. • Analytical ability to interpreter the results involving linear static analysis, Dynamic analysis, Thermal analysis, Buckling analysis etc. • Understanding and working of FEA commercial tools ANSYS/ABAQUES/COMSOL
Assessment Method	Class tests, quiz, Project (By using commercial software/developing own FEA code), Mid semester and End semester Examination.

Suggested Readings:

Text Book:

[1] Reddy, J.N., “An Introduction to Finite Element Methods”, 3rd Ed., Tata McGraw-Hill. 2005.

Reference Books:

[2] Zienkiewicz, O. C. “The Finite Element Method, 3rd Edition, Tata McGraw-Hill. 2002.
[3] Cook, K.D., Malkus, D.S. and Plesha, M.E., “Concept and Applications of Finite Element Analysis”, 3th Ed., John Wiley and Sons. 1989.
[4] Rao, S.S., “The Finite Element Method in Engineering”, 4th Ed., Elsevier Science. 2005.
[5] Reddy, J.N. and Gartling, D.K “The Finite Element Method in Heat Transfer and Fluid Dynamics”, 2rd Ed., CRC Press. 2001.
[6] Fish, J. and Belytschko, T., “A First Course in Finite Elements”, 1st Ed., John Wiley and Sons. 2007.
[7] Chaskalovic, J., “Finite Element Methods for Engineering Sciences”, 1st Ed., Springer. 2008.
[8] Bathe, K. J., “Finite Element Procedures”, 1st Ed., Cambridge Press

Course Number	**ME5104**
Course Credit	L-T-P-Cr : 0-0-3-1.5
Course Title	**Design Lab - I**
Learning Mode	Laboratory experiments
Learning Objectives	Complies with PLOs 3 and 4. Understanding of Data Acquisition System, Signal Processing, Assembly, Running and safety procedures of dynamic machinery such as rotor, motor, brakes, clutches etc.
Course Description	Prerequisite: NIL
Course Outline	1) DAQ and its components, feedback motion control of DC motor, low pass andhigh pass filters, spectrum analysis. 2) Fault Detection in Rotating Machinery. 3) Electrical motor current signature analysis on Machine Fault Simulator 4) Experimental investigation of Oil whirl-Oil whip in Machine Fault Simulator 5) Study of Air Bearing apparatus and its onset whirl 6) Experimental investigation of Rider's comfort through Active mass suspension 7) To determine the frequency response function of a Cantilever Beam 8) To measure the sound pressure level of shop floor/machine with different weighting scale and validation of inverse proportionality law 9) Dynamic Balancing (on MFS) and Field balancing of Rotating machinery 10) Experimental setup built by students themselves / a precursor to M-Tech. project. 11) Use of standards for experiments.
Learning Outcome	Understanding of rotating machinery performance, balancing, performance of tribological elements, Design and fabrication of signal processing resources, Report writing.
Assessment Method	Experiment (40%), Report (10%), Quiz (20%), Viva (30%)

Texts Books:

1. Beckwith T. G., Marangoni, R. D., and Lienhard, J. H., Mechanical Measurements, 5e, Addison Wesley, 1993.
2. Dally, Riley, and McConnell, Instrumentation for engineering measurements, 2e, John Wiley & Sons., 1993.
3. Figiola, R.S. and Beasley, D.E., Theory and design for mechanical measurements, 2(e), John Wiley, 1995.

Department Elective - I						
Sl. No.	**Subject Code**	**Subject**	**L**	**T**	**P**	**C**
1.	ME6105	Acoustics	3	0	0	3
2.	ME6106	Mobile Robotics	3	0	0	3
3.	ME6107	Digital Manufacturing and Industry 4.0	3	0	0	3
4.	ME6108	Wear & Lubrication of Machine Components	3	0	0	3

Course Number	**ME6105**
Course Credit	L-T-P-Cr: 3-0-0-3
Course Title	**Acoustics**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 3 and 4 This course aims to develop an understanding of (a) The basics of the phenomenon of Acoustics (b) Mathematical modelling of the linear phenomenon (c) Application of the models for understanding basic acoustics systems such as Resonators, Filters and Ducts etc. (d) Understanding of Environmental acoustics, Community noise, Architectural noise, Underwater acoustics etc
Course Description	To provide the concepts of acoustics and its applications in wide range of engineering problems. Prerequisite: NIL
Course Outline	Acoustics: Objective-Understanding of Vibration, Sound, Noise. Mathematical basics for Acoustics- PDE, Vectors, divergence (Greens) theorem, Stokes theorem, Signal processing. Development of Wave equation, Helmholtz equation. Acoustic wave equation- Plane waves, Acoustic -Power, Intensity & measurement. Transmission, Absorption and attenuation of sound waves in fluids, Spherical Waves, monopole, dipole, quadropole and piston radiator. Radiation and Reception of Acoustic waves. Active sound control Pipes, Cavities, Waveguides, Resonators, Filters and Ducts- Plane Waves, energy dissipation, finite amplitudes and transmission phenomena, horn radiator, mufflers, silencers Noise, signaldetection, hearings and Speech-Noise spectrum and band level, combining band levels and Tones, Detecting signal in noise, Detection threshold, Ear-Thresholds, Equal loudness level contours, Critical bandwidth, Masking Loudness level, Pitch and frequency Environmental Acoustics- weighted Sound levels, Speech interference, Criteria for Community noise, Highway noise, Aircraft noise rating, Hearing loss, Legislations for Noise control Architectural acoustics, Reverberation time, Sound Absorption materials, Direct and Reverberant Live rooms, Acoustic factors in design Transduction-transducers/transmitters- anti reciprocal, reciprocal. Loudspeakers, Microphones. Introduction to Underwater Acoustics. Use of standards for design.
Learning Outcome	Analysis of Acoustic phenomenon for modeling systems with linear acoustics Understanding and designing systems such as mufflers, resonators, filters, ducts, loudspeakers, microphones etc. Understanding the effect of Acoustics- Community noise, Automotive noise, Architectural acoustics etc
Assessment Method	Mid Semester Examination (30%), End Semester examination (50%), Class test & quiz (10%), Assignment (10%)

Suggested Readings:

Text Books:

1. Fundamental of Physical Acoustics, David T Black Stock, John Wiley & Sons, Inc, 2000
2. Noise and Vibration Control Engineering: Principles and Applications Leo L. Beranek, JohnWiley & Sons, Inc, 2005
3. Handbook of Noise and Vibration Control edited by Malcolm J. Crocker, John Wiley & Sons,Inc., New York, 2007.

Course Number	**ME6106**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Mobile Robotics**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1 and 4 • This course will present various aspects of design, fabrication, motion planning, and control of intelligent mobile robotic systems. • This course presents computational aspects and practical implementation issues and thereby leads to a well rounded training.
Course Description	This course is designed to introduce students to the concepts of Mobile Robotics. The course will provide theoretical background as well as expose the students to practical aspects of Mobile Robotics. Prerequisite: Engineering Mathematics, Linear Algebra
Course Outline	**Robot locomotion:** Types of locomotion, hopping robots, legged robots, wheeled robots, stability, manoeuvrability, controllability **Mobile robot kinematics and dynamics:** Forward and inverse kinematics, holonomic and nonholonomic constraints, kinematic models of simple car and legged robots, dynamics simulation of mobile robots **Perception:** Proprioceptive/Exteroceptive and passive/active sensors, performance measures of sensors, sensors for mobile robots like global positioning system (GPS), Doppler effect-based sensors, vision based sensors, uncertainty in sensing, filtering **Localization:** Odometric position estimation, belief representation, probabilistic mapping, Markov localization, Bayesian localization, Kalman localization, positioning beacon systems **Introduction to planning and navigation:** path planning algorithms based on A-star, probabilistic roadmaps (PRM), Markov Decision Processes (MDP), and stochastic dynamic programming (SDP).
Learning Outcome	After completing this course, the students will be able to design and fabricate a mobile robotic platform and program it to apply learned theoretical concepts in practice.
Assessment Method	Mid Semester Examination, End Semester examination, Class test & quiz, Assignment with simulation and hardware building exercises.

Suggested Readings:

Text / Reference Books:

[1] R. Siegwart, I. R. Nourbakhsh, “Introduction to Autonomous Mobile Robots”, The MIT Press, 2011.

[2] Peter Corke, Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer Tracts in Advanced Robotics, 2011.

[3] S. M. LaValle, “Planning Algorithms”, Cambridge University Press, 2006. (Available online http://planning.cs.uiuc.edu/)

[4] Thrun, S., Burgard, W., and Fox, D., Probabilistic Robotics. MIT Press, Cambridge, MA, 2005.

[5] Melgar, E. R., Diez, C. C., Arduino and Kinect Projects: Design, Build, Blow Their Minds, 2012.

Course Number	**ME6107**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Digital Manufacturing and Industry 4.0**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLO 1 • This course will present various aspects of digital manufacture systems and industry 4.0 with smart and connected business perspective. • This course presents data analytics for digital manufacturing and practical implementation issues for cyber physical systems and thereby leads to a well-rounded training. • This course will also give theoretical and practical knowledge on unmanned aerial vehicle or drone technology, automatic guided vehicles and collaborative robotics essential for industry 4.0
Course Description	This course is designed to discuss t various aspects of digital manufacture systems and industry 4.0 with smart and connected business perspective. The course will describe required tools for cyber physical systems development. This course will also give theoretical and practical knowledge on unmanned aerial vehicle or drone technology, automatic guided vehicles and collaborative robotics essential for industry 4.0 Prerequisite: nil
Course Outline	Digital Manufacturing: theory and industrial applications; Project planning and project management with digital tools; Digital configuration and architecture; Digital manufacturing system modelling, simulation and analysis Industry 4.0: Globalization and emerging issues, the fourth revolution, LEAN production systems, smart and connected business perspective, smart factories; Cyber Physical Systems and next generation sensors; Collaborative platform and product lifecycle management; Augmented Reality and Virtual Reality; Machine Learning and Artificial Intelligence in Manufacturing; Industrial Sensing & Actuation; Industrial Internet Systems Automation and Robotic solution under the umbrella of Industry 4.0: Applications of Unmanned Aerial Vehicles (UAVs), Autonomous Guided Vehicles (AGV); Understanding the application scenarios of UAVs and AGVs for manufacturing; Key components of UAV and AGV - Sensor & Hardware, Understanding of Navigation and Path Planning.
Learning Outcome	After completing this course, the students will be able to develop digital twins of the physical system and program it to apply learned theoretical concepts for implementation of collaborative industry 4.0 platforms in practice.
Assessment Method	Mid Semester Examination, End Semester examination, Class tests, Assignments
Suggested Readings: **Reference Books:** [1] M.P. Groover, “Automation, Production Systems and Computer Integrated manufacturing”, 4th Edition, Pearson Education (2016) [2] Hamed Fazlollahtabar, Mohammad Saidi-Mehrabad, “Autonomous Guided Vehicles: Methods and Models for Optimal Path Planning”, Springer, 2015. [3] K Kumar, D Zindani and J P Davim, “Digital Manufacturing and Assembly Systems in Industry 4.0,” CRC Press, 2019	

[4]	J P Davim, "Manufacturing in Digital Industries: Prospects for Industry 4.0", De Gruyter, 2020
[5]	P. K. Garg, "Introduction To Unmanned Aerial Vehicles," New Age International Private Limited; First edition, 2020
[6]	S.K., Pal, D. Mishra, A. Pal, S. Dutta, D. Chakravarty, S. Pal, "Digital Twin – Fundamental Concepts to Applications in Advanced Manufacturing", Springer, 2021

Course Number	**ME6108**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Wear & Lubrication of Machine Components**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1 and 3 Surface failure due to rubbing is a critical problem that affects the life and reliability of modern machinery. The knowledge of surface interaction is interdisciplinary and essential to design for life and reliability and also enable innovation in electromechanical and material engineering design. The course focuses on theories of friction, wear, contact and lubrication, approaches to model basic tribological elements/systems, and methods to simulate tribological processes.
Course Description	This course is designed to fulfil understanding of theories of friction, wear, contact and lubrication, approaches to model basic tribological elements/systems, and methods to simulate tribological processes. Prerequisite: NIL
Course Outline	Definition Tribology, Significance for Maintenance and Reliability of Machines, Surface – Roughness, Mechanics of surface/solids contact – Hertzian, Non-Hertzian, Modeling of Rough surface contact, Laws of friction, Mechanisms of friction, Stiction, Stick slip, Surface temperature, Surface energy, micro and nano scale friction. Rolling/Sliding – Heathercote Model, Kalker, Wear – Adhesive Wear, Delamination Wear, Fretting Wear, Abrasive Wear, Erosive Wear, Corrosive Wear, Mild and Severe Oxidative Wear, Wear Mechanism Maps, Stribeck Curve, Reciprocatory, Rotary, Macro-pitting, Micro –pitting, Wear in mechanical/electrical contact, Lubrication – regimes: Boundary Lubrication, Solid Film Lubrication, Mixed Lubrication, Hydrodynamic Lubrication, Hydrostatic Lubrication, EHL, Lubrication in vacuum, Bearings – rolling elements, Journal bearing, Gears, Cams, reciprocatory applications – e.g. sliders, piston-cylinders, IC engines-valve-followers, Lubrications and wear control – coatings and material processing, Lubricants – composition, base fluids, rheology, Additives – boundary layer, Nano additives, Tribological tests – friction, Wear, Life tests, Standards, Reciprocatory, Rotary, rolling/sliding –spiral orbit, dry and Lubricated tests, Scaling up subscale tests, component tests, Nano scale testing
Learning Outcome	Understanding of surface contact failures and ways to prevent or increase life of such components. Design of test equipment for testing wear and friction at different scales.
Assessment Method	Assignments, Quiz, Mid term and end term exams

Suggested Readings:
Text Books:

[1] R.D. Arnell, P.B. Davies, J. Halling, T.L. Whomes, Tribology: principles and design applications, Macmillan Education Ltd, First edition 1991.
[2] B. Bhushan, Principles and Applications of Tribology, John Wiley, second edition, 2013.
[3] K.L. Johnson, Contact mechanics, Cambridge University Press, 1987.
[4] A. Cameron, Basic Lubrication Theory, E. Horwood, Halsted Press, 1976.

[5] I. Hutchings, P. Shipway, Tribology: friction and wear of engineering materials, Butterworth-heinemann, 2nd Edition, 2017.
[6] G, Stachowiak, A.W. Batchelor, Engineering tribology, Butterworth-heinemann, Fourth edition, 2013.

Department Elective - II						
Sl. No.	**Subject Code**	**Subject**	**L**	**T**	**P**	**C**
1.	ME6103	Continuum Mechanics	3	0	0	3
2.	ME6109	Vehicle Dynamics and Multi-body Systems	3	0	0	3
3.	ME6110	Biomechanics	3	0	0	3
4.	ME6112	Advanced Mechanical Characterisation of Alloys	3	0	0	3

Course Number	ME6103
Course Credit	**L-T-P-C:** 3-0-0-3
Course Name	**Continuum Mechanics**
Pre-requisites	Mechanics of Solids and Mechanics of Fluids
Learning Mode	Classroom lecture

Course Objectives

Complies with PLOs 1 and 4

- This course targets students of solid and fluid mechanics, aiming to familiarize them with the fundamentals of continuum mechanics by enhancing their problem-solving skills for engineering problems like structural mechanics, fluid dynamics and heat transfer.

Course Content

1. **Mathematical Preliminaries**
   Introduction to Tensors: Vectors and second order tensors; Tensor operation; Properties of tensors; Invariants, Eigenvalues and eigenvectors of second order tensors; Tensor fields; Differentiation of tensors; Divergence and Stokes theorem.
2. **Kinematics of Deformation**
   Continuum hypothesis, Material (Lagrangian) and Spatial (Eulerian) descriptions of motion, Displacement field, Deformation gradient, Stretch ratios, Polar decomposition of deformation gradient, Velocity gradient, Rate of deformation, Vorticity, Length, area and volume elements in deformed configuration; Material and spatial time derivatives - velocity and acceleration, Cauchy stress tensor, state of stress, concept of first and second Piola-Kirchoff stress tensors.
3. **Fundamental Laws in Continuum Mechanics:**
   Material derivatives of Line, Surface and Volume Integrals, Conservation of mass, continuity equation, Conservation of linear and angular momentum, Conservation of energy; Continuum Thermodynamics: Basic laws of thermodynamics; Energy equation; Entropy; Clausius-Duhem inequality.
4. **Constitutive Relations and Material Models:**
   Constitutive Assumptions; Ideal Fluids; Elastic Fluids, Hyperelastic Material; Notion of Isotropy; Isothermal Elasticity - Thermodynamic Restrictions, Material Frame Indifference, Material Symmetry; Hooke's law, Stokes problem, Newtonian and Non-Newtonian fluids.

Learning Outcomes:

- The students will understand the various theoretical elements of continuum mechanics, and how these elements apply to solids and fluids.
- The students will be able to derive and apply the equations of continuum mechanics in the following areas: stress and strain analysis, deformation, work and energy, theory of elasticity, viscoelasticity, theory of plasticity, fluid mechanics, and the basis for constitutive equations.
- The students will be able to use continuum theory descriptions in their research work. Furthermore, it will also be helpful for them to understand research or scientific articles with continuum formulations.

Assessment Method

Mid semester examination, End semester examination, Class test/Quiz, Assignments

Reference Books

1. Mase, G. T., and Mase, G. E., Continuum Mechanics for Engineers, CRC Press, 2nd Edition, 1999.
2. Malvern, L. E., Introduction to the Mechanics of a Continuous Medium, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1969.
3. Rudnicki, J. W., Fundamentals of Continuum Mechanics, John Wiley & Sons, 2015.
4. Lai, W. M., Rubin, D., and Krempl, E., Introduction to Continuum Mechanics, Butterworth-Heinemann, 4th edition, 2015.
5. Reddy, J.N., An introduction to continuum mechanics, Cambridge University Press, 2013.
6. Jog, C.S., Foundations and applications of mechanics: Volume I: Continuum mechanics, Narosa Publishing House, 2007.

Course Number	**ME6109**
Course Credit	**3-0-0-3**
Course Title	**Vehicle Dynamics and Multi-body Systems**
Learning Mode	Lectures and Simulation tools
Learning Objectives	Complies with PLOs 1 and 4 Understanding the dynamics of a wheeled vehicle, various systems- tires and the mechanics, drive trains, steering, braking and suspension systems. Developing models for handling and stability vehicle. Concepts of rigid body dynamic analysis for enabling modeling of vehicle dynamic systems Prerequisite: Engineering Mechanics/Dynamics or equivalent course
Course Description	Wheeled vehicle dynamics with tire mechanics and effect of various subsystems such as drive trains, steering, suspensions, braking. Stability and safety of the vehicle. Basic concepts of rigid body dynamics which go into the mathematical modeling of the vehicle system.
Course Outline	Introduction to vehicle dynamics: Vehicle coordinate systems; loads on axles of a parked car and an accelerating car. Acceleration performance: Power-limited acceleration, traction-limited acceleration. Tire models: Tire construction and terminology; mechanics of force generation; rolling resistance; tractive effort and longitudinal slip; cornering properties of tire; slip angle; camber thrust; aligning moments. Aerodynamic effects on a vehicle: Mechanics of airflow around the vehicle, pressure distribution, aerodynamic forces; pitching, rolling and yawing moments; crosswind sensitivity. Braking performance: Basic equations for braking for a vehicle with constant deceleration and deceleration with wind-resistance; braking forces: rolling resistance, aerodynamic drag, driveline drag, grade, tire-road friction; brakes, anti-lock braking system, traction control, braking efficiency. Steering systems and cornering: Geometry of steering linkage, steering geometry error; steering system models, neutral steer, under-steer, over-steer, steering ratio, effect of under-steer; steering system force and moments, low speed and high speed cornering; directional stability of the vehicle; influence of front wheel drive. Suspension and ride: Suspension types—solid axle suspensions, independent suspensions; suspension geometry; roll center analysis; active suspension systems; excitation sources for vehicle rider; vehicle response properties, suspension stiffness and damping, suspension isolation, active control, suspension non-linearity, bounce and pitch motion. Roll-over: Quasi-static roll-over of rigid vehicle and suspended vehicle; transient roll-over, yaw-roll model, tripping, use of standards for design. Multi-body systems: Review of Newtonian mechanics for rigid bodies and system of rigid bodies; coordinate transformation between two set of axes in relative motion between one another; Euler angles; angular velocity, angular acceleration, angular momentum etc. in terms of Euler angle parameters; Newton-Euler equations of motion; elementary Lagrangian mechanics: generalised coordinates and constraints; principle of virtual work; Hamilton’s principle; Lagrange’s equation, generalized forces. Lagrange’s equation with constraints, Lagrange’s multiplier.
Learning Outcome	Mathematical modeling of the vehicle dynamic system with integrations of various subsystems- Tire, drive trains, suspension, steering, brakes. Understanding of the stability and rollover limits of the vehicle. Use of simulation tools for developing the analytical model and also rigid body analysis tools

Assessment Method	Assignments, Quiz, Mid term and end term exams

Suggested Readings:

1. T.D. Gillespie, “Fundamental of Vehicle Dynamics”, SAE Press (1995).
2. J.Y. Wong, “Theory of Ground Vehicles”, 4th Edition, John Wiley & Sons (2008).
3. Reza N. Jazar, “Vehicle Dynamics: Theory and Application”, 1st Edition, Springer (2008).
4. R. Rajamani, “Vehicle Dynamics and Control”, Springer (2006).
5. A.A. Shabana, “Dynamics of Multibody Systems”, 3rd Edition, Cambridge University Press (2005).

Reference Book

1. G. Genta, “Motor Vehicle Dynamics”, World Scientific Pub. Co. Inc. (1997).
2. H.B. Pacejka, “Tyre and Vehicle Dynamics”, SAE International and Elsevier (2005).
3. Dean Karnopp, “Vehicle Stability”, Marcel Dekker (2004).
4. U. Kiencke and L. Nielsen, “Automotive Control System”, Springer-Verlag, Berlin.
5. M. Abe and W. Manning, “Vehicle Handling Dynamics: Theory and Application”, 1st Edition, Elsevier (2009).
6. L. Meirovitch, “Methods of Analytical Dynamics”, Courier Dover (1970).
7. H. Baruh, “Analytical Dynamics”, WCB/McGraw-Hill (1999).

Course Number	**ME6110**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Biomechanics**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1 and 4 The objectives of this course are: • Recognize different forces and couples acting on a Biological systems. • Should be able to unify the biological system as a Continuum and demarcate the different elements of biological system such as bone, tendon, cartilage and smooth muscle cells. • Analyze the growth, remodelling and residual stress. • Perform the experiment on RBC like system, viscosity measurement blood-like liquid, ECG, blood pressure, pressure distribution of human walk on the foot, determination of residual stress overgrowth. • Model some of the biological system through computational technique. • Able to identify a few of instrumentation technique like ECG, EEG, blood flow, respiratory systems • Should be able to mathematically analyse a simple injury of biological system from impact and able to perform the preventive design from the first principle.
Course Description	This course is designed to fulfil the requirement of designing biological systems from the engineering perspective by imparting the some knowledge of biological system through analytical way. Prerequisite: NIL
Course Outline	**Introduction to Biological System** Cell, Tissues and Connective Tissues and their Phenomenological Models: Bone, Tendon, Cartilage, Smooth Muscle cells, Musculo-Skeletal system as a tensegrity structure Gait Analysis: Locomotion and Control Modeling of Humanoid Robots Physiology and mechanical properties of muscles- Viscoelastic model of muscle Tentanization pulse in muscle fibers Physiology and mechanical properties of bones- Bones as bidirectional fibers-nets and its stress response **Circulation system** Composition and rheological properties of blood Construction of RBC Composition of Artery and Venus walls Operation of heart as a pump and electrical potential **Neural system and control** Central nervous system Auxiliary nervous system

	Experiment on Biological system- Experiment on RBC like system, viscocity measurement blood-like liquid, ECG, blood pressure, pressure distribution of human walk on the foot **Growth, Remodeling and Residual Stresses** Mathematical model of growth Mathematical model of tumor Remodeling of biological tissues like skin, artery- wrinkle of skin, ageing of artery Modeling of Residual stress **Experiment on Biological system-** Determination of residual stress in artery-like tissue Determination of ageing affect on arterial tissue **Instrumentation Technique in Biomechanics** Measurement of Biopotential – ECG, EMG, ENG,… Test on Respiratory Mechanism Ultrasonic measurement of Blood flow Drug Delivery Systems **Application of Biomechanics** Sports Biomechanics Artificial Limbs and organs Occupational Biomechanics- consideration in Machine Control and Workplace Design Injury Biomechanics – Analysis and optimal design **Biomaterial**
Learning Outcome	Following learning outcomes are expected after going through this course. a) Will be able to model a biological system both analytically and numerically. b) Will be able to apply the knowledge of Electro-Magnetic Interference to design different instruments like ECG, EEG and EMG. c) Will be able obtain the interpretation of biological system in growth, remodelling and residual stresses to predict through model the circulation system of human body. d) Will be able to identify the different sophisticated instrumentation technique like MRI, Colour Angiogram, Elastogram in qualitative and quantitative way to identify the diseased cells. e) Will be able to design and develop different biological instruments/actuators/device/artificial limbs needed for the society.
Assessment Method	Mid Semester Examination (30 %), End Semester examination (50%), Class test & quiz (10%), Assignment (10%)

Suggested Readings:
Text Books:

1.	Jay D. Humphrey and Sherry DeLange “An Introduction to Biomechanics: Solids and Fluids, Analysis and Design”, Springer; 1st Edition	2004
2.	Roger Bartlett “Introduction to Sports Biomechanics: Analysing Human Movement Patterns” Routledge; 2nd Edition	2007

3.	STEPHEN C. COWIN AND JAY D. HUMPHREY Edt. , "Cardiovascular Soft Tissue Mechanics ", Kluwer Academic Publishers	2000
4.	Walter D. Pilkey, Dmitry V. Balandin, Nikolai N. Bolotnik, "Injury Biomechanics and Control: Optimal Protection from Impact ", 1st Edition., Wiley .	2009
5.	Don B. Chaffin, Gunnar B. J. Andersson, Bernard J. Martin "Occupational Biomechanics", Wiley-Interscience; 3rd Edition	1999
6.	John G. Webster, "Medical Instrumentation: Application and Design", Wiley; 3rd Edition	1997

Course Name	Advanced Mechanical Characterisation of Alloys
Course Number	**ME6112**
L-T-P-C	3-0-0-3
Pre-requisites	Nil
Learning Mode	Class room lecture

Course objectives

Complies with PLOs 2 and 4

- Impart a thorough understanding of the mechanical behaviour of materials under various conditions.
- Teach students how to interpret the results of mechanical tests.
- Apply this knowledge to solve real-world engineering problems.

Course Content

1. **Introduction**

Fundamentals of elastic and plastic deformation
Yield criteria, von Mises, Tresca, Hill 48, Hill 1993
Defects in materials
Role of dislocations, twinning, and slip in plastic deformation
Strengthening mechanisms in alloys
Ductile and brittle failure, intergranular and transgranular failure, GTN model
Influence of temperature, strain rate, and environment on plastic deformation
Application of mechanical properties in engineering design

2. **Monotonic Tests**

Tensile, compression, shear, and torsion tests
Bend test and notch tensile test
Macro, micro, and nano hardness tests
Wear testing
Hydrogen embrittlement evaluation

3. **Fatigue**

Oligocyclic fatigue, Low cycle fatigue, high cycle fatigue, and giga cycle fatigue
Concept of endurance limit, effect of mean stress
Basquin and Coffin-Manson laws, strain energy density laws for life prediction
Cyclic stress-strain curve analysis
Masing analysis
Cyclic hardening/softening
Notch fatigue
Thermo-mechanical fatigue
Rolling contact fatigue
Fretting fatigue
Effect of hydrogen embrittlement on fatigue
Influence of defects and microstructural inhomogeneity on fatigue

4. **Fracture**

Stress concentration factor and stress intensity factor
Griffith theory
Basics of linear elastic and elastoplastic fracture mechanics
Impact toughness and ductile to brittle transition
Fracture toughness and concepts of K_{1c} and J_{1c}, CTOD, Mode mixity,
Fatigue Crack Growth Rate (FCGR), and Paris law
Short crack growth and concept of K_{th}

5. **Creep**
   Creep and creep crack growth
   Stress relaxation tests
   Creep-fatigue interaction

6. **High Rate Deformation**
   Strain rate sensitivity
   Crash testing
   Crashworthiness of engineering components

7. **Sheet Metal Forming**
   Concept of planar anisotropy and texture
   Forming limit diagram, Wrinkling limit, fracture limit curve
   Hole expansion ratio
   Bauschinger effect and spring back
   r-ratio and deep drawing ratio

Learning Outcomes:

By the end of this course, undergraduate students should be able to:

- Demonstrate a comprehensive understanding of various advanced mechanical properties.
- Interpret various mechanical tests
- Apply knowledge of advanced mechanical properties to solve real-world engineering problems and enhance material performance.

Assessment Method

- Quiz, mid and end-semester examinations

Texts and References

Text Books:

1. George E. Dieter, Mechanical Metallurgy, McGraw Hill Education, 3rd Edition, 1 July 2017.
2. S. Suresh, Fatigue of Materials, Cambridge University Press, 2nd edition, June 2012.
3. T.L. Anderson, Fracture Mechanics: Fundamentals and Applications, CRC Press, 4TH EDN, 2017.
4. M.N. Shetty, Dislocation and mechanical behaviour of materials, PHI, 2013.

Reference Books:

1. Prashant Kumar, Elements of Fracture Mechanics, McGraw Hill Education, 2017.
2. J. Schijve, Fatigue of Structures and Materials, Springer, 2nd ed. 2009.
3. Bruno C. De Cooman and Kip O. Findley, Introduction to the Mechanical Behavior of Steel, Association for Iron & Steel Technology, 30 Nov 2017.

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	ME5201	Advanced Engineering Software Lab	1	0	4	3
2.	ME5202	Advanced Dynamics & Vibration	3	1	0	4
3.	ME5203	Measurement and Instrumentation	3	0	0	3
4.	ME5204	Design Lab - II	0	0	3	1.5
5.	ME62XX	DE-III	3	0	0	3
6.	ME62XX	DE-IV	3	0	0	3
7.	RM6201	Research Methodology	3	1	0	4
8.	IK6201	IKS	3	0	0	3
	TOTAL		**19**	**2**	**7**	**24.5**

Course Number	**ME5201**
Course Credit	L-T-P-C: **1-0-4-3**
Course Title	**Advanced Engineering Software Laboratory**
Learning Mode	Classroom Lectures and Practical
Learning Objectives	Complies with PLOs 1-4. Exposure to industrial software used in Mechanical Engineering practices.
Course Description	This course is designed to make students understand commercial software along with the understanding of numerical al techniques.
Course Outline	**CAD/CAM**: 2D and 3D geometric transformation, Composite Transformation, Projections; Curves: Cubic, Bezier, Splines; Surfaces: Quadric, Coons patch, Super Quadric, Bezier, B-Splines. Process planning, CL data generation, Automatic CNC code generation. **FEM**: Solid model creation, different types of elements, chunking of model, meshing, mesh quality, different kinds of analysis: static, dynamic, transient, thermal, electro-magnetic, acoustics, sub- structuring and condensation, Error and convergence. Non-linear static and dynamic analysis, contact analysis, multi-physics problem, rigid body analysis of flexible element. **CFD**: Different types of CFD techniques, various stages of CFD techniques (i) pre-processor: governing equations, boundary conditions, grid generation, different discretization techniques (ii) processor: solution schemes, different solvers (iii) post-processing: analysis of results, validation, grid independent studies etc. Developing codes using commercial/open source software for solving few problems of laminar and turbulent flow with heat transfer applications. Engineering software's related to CAD/CAM, FEM, CFD, with both GUI and script like languages, are to be used for laboratory assignments.
Learning Outcome	At the end of the course, students will be able to use the industrial software for simulating industrial and research problems related to solid and fluid mechanics. A mature understanding of various numerical techniques and their advantages and disadvantages will develop with respect to the software used in the class.
Assessment Method	Class test & quiz, Assignment, Class Performance and Viva, Practical Exam

Suggested Readings:

1. D. F. Rogers and J. A. Adams, "Mathematical Elements for Computer Graphics", McGraw- Hill, 1990
2. M. Groover and E. Zimmers, "CAD/CAM: Computer-Aided Design and Manufacturing", Pearson Education, 2009.
3. Saxena and B. Sahay, "Computer Aided Engineering Design", Springer, 2007.
4. J. N. Reddy, "An Introduction to Finite Element Methods", 3rd Ed., Tata McGraw-Hill, 2005.
5. J. Fish, and T. Belytschko, "A First Course in Finite Elements", 1st Ed., John Wiley and Sons, 2007.
6. J. D. Anderson, "Computational Fluid Dynamics", McGraw-Hill Inc. (1995).
7. H. K. Versteeg and W. Malalaskera, "An Introduction to Computational Fluid Dynamics", Dorling Kindersley (India) Pvt. Ltd. (2008).
8. S. Biringen and C Chow, An Introduction to Computational Fluid Mechanics by Example.

Course Number	**ME5202**
Course Credit	L-T-P-Cr : 3-1-0-4
Course Title	**Advanced Dynamics and Vibration**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1 and 4. This course aims to understand the fundamentals of rigid body dynamics, vibration of single and multi-degrees of freedom system with introduction to nonlinear dynamics.
Course Description	This course is designed to fulfil mathematical modelling and physics of rigid body dynamics, vibration of discrete and continuous system. Prerequisite: NIL
Course Outline	Review of Newtonian mechanics for rigid bodies and system of rigid bodies; coordinate transformation between two set of axes in relative motion between one another; Euler angles; angular velocity, angular acceleration, angular momentum etc. in terms of Euler angle parameters; Newton-Euler equations of motion; elementary Lagrangian mechanics: generalized coordinates and constraints; principle of virtual work; Hamilton's principle; Lagrange's equation, generalized forces. Lagrange's equation with constraints, Lagrange's multiplier. Nonlinear effects in Dynamics. Review of the single DOF system and simple Multi-DOF lumped parameter systems. Equations of motion for free and forced vibration of distributed parameter systems: axial vibration of a bar, transverse vibration of a string, torsional vibration of a shaft, transverse vibration of beams. Boundary-value problem and boundary conditions. Differential eigenvalue problem, eigen-function and natural modes. Orthogonality of eigen-functions and expansion theorem. Rayleigh quotient. Response to initial conditions and external excitations. Discretization of distributed parameter system: Algebraic eigenvalue problem, eigenvalue and eigenvectors. Introduction to Modal analysis.
Learning Outcome	Mathematical modelling of dynamics system with rigid body and vibratory system.
Assessment Method	Mid Semester Examination (30%), End Semester examination (50%), Class test & quiz (10%), Assignment (10%)

Suggested Readings:

Text Books:

1. H. Baruh, Analytical Dynamics, McGraw-Hill, 1999.
2. L. Meirovitch, Methods of Analytical Dynamics, Dover Publication, 2010.
3. D.T. Greenwood, Principles of Dynamics, Prentice-Hall International, 1988.
4. A.A. Shabana, Dynamics of Multibody Systems, 4th Cambridge UniversityPress, 2013.
5. L. Meirovitch, Fundamentals of Vibration, McGraw Hill, 2000.
6. W.T. Thompson, M.D. Dahleh, C. Padmanabhan, Theory of Vibration with Application, 5th Ed., Pearson, 2008.
7. S.S. Rao, Mechanical Vibration, 4th Ed., Pearson, 2004.
8. W. Weaver, Jr., S.P. Timoshenko, D.H. Young, Vibration Problems in Engineering, 5th Ed., John Wiley and Sons, 1990.

Course Number	**ME5203**
Course Credit	L-T-P-C: 3-0-0-3
Course Title	**Measurement and Instrumentation**
Learning Mode	Classroom lecture
Learning Objectives	Complies with PLOs 1-3. The course aims to provide a basic understanding of the mechanical measurement systems and statistical analysis of experimental data.
Course Description	The course contains the generalized configuration and functional elements of measuring systems, static and dynamic characteristics of measuring instruments. The course also includes the instrumentation for displacement, strain, velocity, force, torque, power, pressure, sound, flow and temperature measurement.
Course Outline	Module-1 Basic concepts of measurement, functional elements of instruments, classification of measuring instruments, methods of correction for interfering and modifying inputs, static characteristics of measuring instruments Module-2 Static characteristics of measuring instruments, loading effect and impedance matching, statistical analysis, Chi-square test, least square method, Curve Fitting, Uncertainty analysis and error propagation Module-3 Generalized model of a measuring system, zero and first order system, second order system. First order system- ramp response, impulse response, frequency response, Second order system- step response, ramp response, impulse and frequency response, higher order systems, compensation, transducers Module-4 Flow measurement (hot wire anemometer, PIV systems, coriolis flow meter, etc.,) temperature measurement (thermocouple, RTD, Infra thermography etc.), heat flux sensors. Optical Methods- Shadowgraph, Schilieren and Interferometer. Module-5 Strain gauges, piezoelectric transducers pressure measurement, force and torque measurement, displacement and acceleration measurement Module-6 Sound measurement, thermophysical properties measurement, flow visualization, air pollution sampling and measurement, pollutants-Gas Chromatography.
Learning Outcome	• Students will be able to analyze and behavior and characteristics of various measuring instruments and record data • Students will be able to analyze and interpret the experimental data • Students will be able to perform uncertainty analysis in the measured and derived quantities.
Assessment Method	Mid Semester Examination, End Semester examination, Quiz, assignments seminar

Textbook

1. E.O. Doebelin, Measurement Systems: Application and Design.

Reference books

2. E.G.R. Eckert and R.G. Goldstein, Measurement Techniques in Heat Transfer.
3. T.P. Holeman, Experimental Methods for Engineers.
4. H.D. Young, Statistical Treatment of Experimental Data.

Course Number	**ME5204**
Course Credit	L-T-P-Cr : 0-0-3-1.5
Course Title	**Design Lab - II**
Learning Mode	Laboratory experiments
Learning Objectives	Complies with PLOs 2 and 3. This course aims to experimentally evaluate the strength of material and fracture mechanics based on materials parameters.
Course Description	This course discusses the experimental evaluation of Mode I fracture toughness, stress concentration, fatigue crack growth mode shapes and measurement of natural frequencies of vibration. Prerequisite: NIL
Course Outline	1) Measurement of Mode I fracture toughness of an Aluminum alloy and PMMA using a compact tension (CT) specimen. 2) Measurement of fatigue crack growth and determination of Paris law parameters for an Aluminum alloy using a CT specimen. 3) Measurement of strains using strain gauges. 4) Determination of ductile to brittle transition temperature of Mild Steel and Aluminum using Charpy Impact Testing Machine. 5) Torsion of bars of non-circular cross-section. 6) Measurement of stress concentration factor in a specimen with holes using photo- -elasticity method. 7) Observation of mode shapes and measurement of natural frequencies of vibration of a circular plate. 8) Detection of location and size of the crack in a cracked beam using deflection measurement method. 9) Scanning Electron Microscopy examination of fracture surfaces of specimens fractured in experiment. 10) Use of standards for experiments.
Learning Outcome	Understanding of fundamentals of experimentally evaluating the strength of material and fracture mechanics based materials parameter.
Assessment Method	Experiment (40%), Report (20%), Quiz (10%), Viva (30%)

Suggested Readings:

Texts Books:

1. Holman J.P., Experimental Methods for Engineers, McGraw Hill Series in Mechanical Engineering, ISBN-10: 0073529303, 8th Editions, 2011.
2. Doebelin E.O., Measurement systems- Applications and Design, 4e, Tata McGraw-Hill, 1990.
3. Dally, Riley, and McConnell, Instrumentation for engineering measurements, 2e, John Wiley & Sons., 1993.
4. Figiola, R.S. and Beasley, D.E., Theory and design for mechanical measurements, 2(e), John Wiley, 1995.

Department Elective - III						
Sl. No.	**Subject Code**	**Subject**	**L**	**T**	**P**	**C**
1.	ME6207	Rotor Dynamics	3	0	0	3
2.	ME6208	Robot Motion Planning	3	0	0	3
3.	ME6209	Non-linear Systems Dynamics	3	0	0	3

Course Number	**ME6207**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Rotor Dynamics**
Learning Mode	Classroom Lecture
Learning Objectives	This course aims to understand Rotor systems, Mathemtical modeling and design of Rotor systems
Course Description	Complies with PLOs 1 and 3 This course is designed to fulfil requirements for modeling and analysis of Rotor systems with applications in bearings, seals, turbines and other state of the art systems. Prerequisite: Dynamics or equivalent course
Course Outline	Rotor-Bearing Interaction, Flexural Vibration, Critical Speeds of Shafts, Jeffcott Rotor Model, Unbalance Response, Effect of Damping, Campbell Diagram, Effects of Anisotropic Bearings, Unbalanced Response of an Asymmetric Shaft, Parametric Excitation, Gyroscopic Effects, Rotor with Non-central Disc, Rigid-rotor of Flexible Bearings, Stodola Model, Effect of Spin Speed on Natural Frequency, Forward and Backward Whirling Motion, Aerodynamic Effects, Instability: Rub, Tangential forces, Rotor-shaft Continuum, Effect of Rotary Inertia and Shear-Deformation within the Shaft, Equivalent Discrete System, Finite Element model for Flexural Vibration, Torsional Vibration, Geared and Branched Systems, Transfer Matrix Model, Fluid Film Bearings: Steady State Characteristics of Bearings, Reynolds's Equation, Oil-Whirl, Rigid And Flexible Rotor Balancing, Active Vibration Control of Rotor-Bearing System: Active Magnetic Bearing, Condition Monitoring of Rotating Machinery, Measurement Techniques. Rolling element bearings, Fault diagnosis.
Learning Outcome	Mathematical modeling and physics understanding of rotor systems as a dynamic system- stability and control with rigid and flexible systems. Application of rotor systems with supporting systems of seals, bearings etc and the ensuing diagnostics
Assessment Method	Mid Semester Examination (30%), End Semester examination (50%), Class test & quiz (10%), Assignment (10%)

Suggested Readings:

Text Books:

1. J. S. Rao, Rotor Dynamics, Third ed., New Age, New Delhi, 1996 (2009 reprint).
2. M. J. Goodwin, Dynamics of Rotor-Bearing Systems, Unwin Hyman, Sydney, 1989.

Reference Books:

1. E. Krämmer, Dynamics of Rotors and Foundation, Springer-Verlag, New York, 1993.
2. G. Genta, Dynamics of Rotating Systems, Springer, New York, 2005.
3. J.M. Vance, Rotordynamics of Turbomachinery, Wiley, New York, 1988.
4. M.L. Adams, Rotating machinery vibration: from analysis to troubleshooting, Seconded., CRCPress, Boca Raton, 2010.
5. J. Kicinski, Rotor dynamics, Tech. Book, New Delhi, 2010.

6. D. Childs, Turbomachinery Rotordynamics: Phenomena, Modeling and Analysis,Wiley, NewYork, 1993.
7. Y. Ishida, T. Yamamoto, Linear and Nonlinear Rotordynamics: A Modern TreatmentwithApplications, 2nd Edition, Wiley, 2012.
8. J.P. Den Hartog, Mechanical Vibration, Courier Dover Publication, 2013.
9. R. Tiwari, Simple Rotor Analysis Through Tutorial Problems, CRC Press, 2023.
10. R. Tiwari, Rotor systems: Analysis and Identification, CRC press, 2017.

Course Number	**ME6208**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Robot Motion Planning**
Pre-requisite	Mobile Robotics
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1 and 4 • This course covers the prominent motion planning algorithms used in the area of mobile robotics. • The course will cover various motion planning algorithms and analyses.
Course Description	This course introduces students to motion planning algorithm theory and implementation which is a crucial enabling technology for imparting higher degree of autonomy to robots. Prerequisite: ME6106 Mobile Robotics
Course Outline	**Configuration space and topology:** Homeomorphism and diffeomorphism, differential manifolds, connectedness and compactness, parameterization of SO(3) **Potential functions:** Additive attractive/repulsive potential, distance computation using Brushfire algorithm, local minima problem, wave-front planner, navigation potential functions, sphere-space and star-space, potential function in non-Euclidean spaces **Roadmaps:** Visibility maps, Generalized Voronoi Diagram, Retract-like Structures, Canny's Roadmap algorithm, opportunistic path planner **Cell decomposition:** Trapezoidal decomposition, Morse cell decompositions, Visibility-based decompositions for Pursuit/Evasion; **Sampling-based algorithms:** Probabilistic roadmaps, Expansive spaces trees, Rapidly-Exploring Random Trees, Analysis of PRM.
Learning Outcome	After completing this course, the students will be able to implement and analyse robot motion planning algorithms.
Assessment Method	Mid Semester Examination, End Semester examination, Class test and quiz, Programming Assignments

Suggested Readings:

Text Book:

[1] H. Choset, K. M. Lynch, S. Hutchinson, G. Kantor, W. Burgard, L. E. Kavraki and S. Thrun, Principles of Robot Motion: Theory, Algorithms, and Implementations, MIT Press, Boston, 2005.

Reference Book:

[1] S. M. LaValle, "Planning Algorithms", Cambridge University Press, 2006. (Available online http://planning.cs.uiuc.edu/)

Course Number	**ME6209**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Nonlinear System Dynamics**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1, 3 and 4 The objective of this course is, • To impart the ability of solving different nonlinear systems through analytical approach • To impart the ability of solving different nonlinear systems through numerical approach as well • To impart the ability of analyzing nonlinear systems through fixed points, phase portrait, linear and nonlinear stability approaches. • To impart the ability of analysing nonlinear system design by identifying subharmonic and superharmonic resonance, Poincare map, Liapnouv exponent. • To impart the ability of identifying Chaos and Factals in engineering systems.
Course Description	This course is designed to fulfil the requirement of designing engineering systems considering the nonlinearity in the system, which is usually ignored in system design. Prerequisite: Dynamics/Engineering Mechanics
Course Outline	**Introduction to Nonlinear Dynamical System**: Linear vs. nonlinear behavior, Classification of nonlinear Systems, Examples of structural, fluid-mechanical and chemical/biological systems, Existence and uniqueness of solutions. **First-order nonlinear systems**: Autonomous systems: Equilibrium points, linear systems,invariant sets, linearization, phase diagrams and velocity fields, behavior dependence on parameters, bifurcations of equilibria (saddle-node, pitchfork and transcritical), implicit function theorem. Nonautonomous systems. **Second-order nonlinear conservative/nonconservative systems**: Phase plane analysis, equilibrium points, linearization, stability, periodic orbits and saddle points, potential function and phase portrait, parameter-dependent conservative systems, local bifurcations, examples of global bifurcations, effect of dissipative forces. **First-order system in the plane**: General phase plane analysis, linearization, general solution for linear systems, classification of equilibrium points, limit cycles, Bendixon's criterion and Poincare Bendixon theorem. Point mapping techniques, exact transformations, and Poincare mappings. **One-dimensional linear and nonlinear mappings**: Fixed points, linearization, stability, parameter- dependent mappings, bifurcations. **Perturbation and other approximate methods**: Introduction to regular and singular perturbation expansions through algebraic and transcendental equations; roots of equations and dependence on parameters. Perturbation method for free oscillations, secular terms, frequency dependence on response, Poincare-Lindstedt technique for

	periodic solutions, Harmonic balance and Fourier series for periodic solutions. Averaging methods, amplitude and frequency estimates, slowly varying amplitude and phase ideas, self-excited oscillations. Multiple time-scale techniques. Forced oscillations, concept of a resonance, oscillations far from resonance, near resonances and strong and weak excitations, response near primary resonance, softening and hardening nonlinearities, Duffing's equation and primary and secondary resonances, forced response of self excited systems near resonance, frequency locking and entrainment. General linear systems with constant and periodic coefficients: Concepts of stability (Lyapunov, Poincare, etc.), stability by linearization, boundedness of solutions, Mathieu's equation, transition curves and periodic solutions for Mathieu-Duffing system. **Relaxation oscillations**: The van der Pol oscillator. **Multi degree of freedom systems**: Examples, various types of resonances – external, internal, and combination, etc., response prediction using methods of averaging and multiple scales. Some more on bifurcations, structural stability and chaos. **Experimental Demonstration**: String ballooning motion. Fun with Cantilever beam of large deformation and other developed models. Electronic Circuit building. Numerical computation with Matlab/ Mathematica.
Learning Outcome	Following learning outcomes are expected after going through this course. • Will be able to solve nonlinear system of equations both analytically and numerically. • Will be able to apply the method of multiple scale, perturbation method, harmonic balance for solving a set of nonlinear differential equations. • Will be able obtain the interpretation of nonlinear system behavior over the linear system behavior. • Will be able to identify the Chaos in engineering system and will be able to quantify through various measures. • Will be able to derive and analyse nonlinear system behavior.
Assessment Method	Mid Semester Examination (30%), End Semester examination (50%), Class test & quiz (10%), Assignment (10%)

Suggested Readings:
Text Books:

1. Jordan, D. W. and Smith, P.: Nonlinear Ordinary Differential Equations, 3rdEdition,Clarendon Press, Oxford, 1999 ed.
2. Nayfeh, A. H. and Mook, D. T.: Nonlinear Oscillations, Wiley Interscience, NewYork., 1979ed.
3. Nayfeh, A. H and Balachandran, B. : Applied Nonlinear Dynamics: Analytical,Computational and Experimental Methods, Wiley, 2008 ed.
4. Strogatz, S. H. : Nonlinear Dynamics And Chaos: With Applications To Physics,Biology,Chemistry, And Engineering, Westview Press, 2001 ed.
5. Ogorzalek Maciej J.:Chaos and Complexity in Nonlinear Electronic Circuits, WorldScientificSeries on Nonlinear Science Series A, 1997 ed.

Department Elective - IV						
Sl. No.	**Subject Code**	**Subject**	**L**	**T**	**P**	**C**
1.	ME6210	Robotics: Advanced Concepts & Analysis	3	0	0	3
2.	ME6211	Analysis of Welding Processes	3	0	0	3
3.	ME6212	Fracture and Fatigue	3	0	0	3

Course Number	**ME6210**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Robotics: Advanced Concepts and Analysis**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1 and 4 • This course gives various aspects of kinematics, dynamics, motion planning, and control of robotic manipulators • This course presents computational aspects, control aspects and practical implementation of multi degree of freedom manipulators for industrial application
Course Description	This course is designed to fulfil the basic and advanced concepts of kinematics, dynamics, motion planning, and control of industrial Robotics. The course will provide theoretical background as well as expose the students to practical aspects of Robotic manipulators. Prerequisite: NIL
Course Outline	Introduction to robotics: brief history, types, classification and usage and the science and technology of robots. Kinematics of robot: direct and inverse kinematics problems and workspace, inverse kinematics solution for the general 6R manipulator, redundant and over-constrained manipulators. Velocity and static analysis of manipulators: Linear and angular velocity, Jacobian of manipulators, singularity, static analysis. Dynamics of manipulators: formulation of equations of motion, recursive dynamics, and generation of symbolic equations of motion by computer simulations of robots using software and commercially available packages. Planning and control: Trajectory planning, position control, force control, hybrid control Industrial and medical robotics: application in manufacturing processes, e.g. casting, welding, painting, machining, heat treatment and nuclear power stations, etc.; medical robots: image guided surgical robots, radiotherapy, cancer treatment, etc. Advanced topics in robotics: Modelling and control of flexible manipulators, wheeled mobile robots, bipeds, etc. Future of robotics.
Learning Outcome	• After completing this course, the students will be able to design and fabricate a robotic arm for some practical applications • Students will able to operate and control a robotic system using the theoretical concepts learned in this course
Assessment Method	Mid Semester Examination, End Semester examination, Class tests, Assignments, mini-projects

Suggested Readings:

Reference Books:

[1] M. P. Groover, M. Weiss, R. N. Nagel and N. G. Odrey, "Industrial Robotics-Technology, Programming and Applications", McGraw-Hill Book and Company (1986).
[2] S. K. Saha, "Introduction to Robotics", Tata McGraw-Hill Publishing Company Ltd. (2008).
[3] S. B. Niku, "Introduction to Robotics–Analysis Systems, Applications", Pearson Education (2001).
[4] A. Ghosal, Robotics: "Fundamental Concepts and Analysis", Oxford University Press (2008).
[5] Pires, "Industrial Robot Programming–Building Application for the Factories of the Future", Springer (2007).
[6] Peters, "Image Guided Interventions – Technology and Applications", Springer (2008).

[7] K. S. Fu, R. C. Gonzalez and C.S.G. Lee, “ROBOTICS: Control, Sensing, Vision and Intelligence”, McGraw-Hill (1987).
[8] J. J. Craig, “Introduction to Robotics: Mechanics and Control”, 2nd edition, Addison-Wesley (1989).

Course Number	**ME6211**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Analysis of Welding Processes**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLO 1 This course aims to impart (a) the fundamental concepts and process details of fusion and non-fusion welding processes, (b) analysis of the processes focusing the role of process parameters, heat generation, heat distribution and metallurgical aspects, (c) weld design and testing aspects of welded joints.
Course Description	This course is designed to fulfil the concepts, process behavior, and analysis of various fusion and non-fusion welding processes, metallurgical aspects, and quality, testing of welded joints. Prerequisite: Basic course on Manufacturing Processes that covers welding processes or equivalent course
Course Outline	Fundamentals of fusion welding – different arc welding techniques; Welding power source: behavior, characteristics, analysis; Physics of Arc; Heat generation, 2D/3D heat flow and heat transfer analysis; Physics and analysis of metal transfer in arc welding, forces on metal pool; Process characteristics of some common arc welding processes e.g. SMAW, TIG, GMAW, SAW etc.; Concepts of flux activated welding, pulsed current welding. Review of different non-fusion welding techniques; Analysis of heat generation during friction, friction stir welding techniques; Fundamentals and applications of other non-fusion welding etc. Welding metallurgy: Heat flow, cooling rate and metallurgical transformations, solidification and cracking; Phase transformations-weld CCT diagrams; Welding of steels – Schaffler and Delong diagrams, Weld metallurgy of Non-ferrous alloys. Welding symbols and concepts of joint design; Weld defects; Joint quality assessments by destructive and non-destructive testing.
Learning Outcome	After completing the course, the students will be able to (a) identify the process characteristics and behavior of fusion, non-fusion welding processes, (b) perform thermal analysis, and appraise the metallurgical changes in welded joints, (c) suitably design for the weld and assess the weld quality.
Assessment Method	Mid Semester Examination, End Semester examination, Assignments and Quiz

Suggested Readings:

Text Books:

[1] A.C. Davies, The Science and Practice of Welding, Vol-2: The Practice of Welding; Cambridge University Press, 2002.

[2] D. J. Hoffman, K. R. Dahle, D. J. Fisher, Welding; Pearson publication, 2017.

Reference Books:

[1] R.W. Messler, Principles of Welding: Processes, Physics, Chemistry, and Metallurgy; John Wiley & Sons, 1999.

[2] R. Little, Welding and Welding Technology, McGrawHill, 2017.

[3] S. Kou, Welding Metallurgy, Second Ed., John Wiley & Sons, 2003.

[4] Fundamentals of Welding, Welding Handbook, Part-I, American Welding Society, 1976.

[5] Metals and their Weldability, Welding Handbook, Part-4, American Welding Society, 1982.

Course Number	**ME6212**
Course Credit	L-T-P-Cr : 3-0-0-3
Course Title	**Fracture & Fatigue**
Learning Mode	Classroom Lecture
Learning Objectives	Complies with PLOs 1, 3 and 4 To provide the analytical and mathematical concepts of fracture mechanics and its applications in wide range of engineering problems.
Course Description	This course discusses topics starting from Griffith's theory of brittle failures, linear elastic fracture mechanics, Irwin's stress intensity factors; Linear elastic fracture mechanics: crack tip stress and deformation fields, Stress intensity factor (SIF) SIF and ERR; First order estimate of plastic zone using Irwin's and Dugdale approach; Elasto-plastic fracture: J-integral and CTOD, Mixed mode fracture; Experimental evaluation of Fracture Toughness, J integrals, Crack nucleation and growth, Fatigue crack growth theories, Fatigue life prediction. **Prerequisite:** Knowledge of solid mechanics or equivalent course
Course Outline	**Introduction**: Background; Griffith theory of fracture, energy release rate (ERR), conditions for stable and unstable crack growth, crack arrest **Linear elastic fracture mechanics**: Stress field at the tip of a crack, solution of stress and displacement field for plane cracks using complex methods in plane elasticity. Stress intensity factor (SIF) for plane and penny shaped cracks, Embedded Cracks, Equivalence of SIF and ERR, fracture toughness. **Elasto-plastic fracture mechanics**: First order estimate of crack tip plastic zone using Irwin's and Dugdle's approach, Plastic zone for plane stress and plane strain situation and effect on fracture toughness, Review of small strain plasticity, Crack tip fields in an elasto-plastic material (Discussion on HRR fields) J-integral as a fracture parameter and crack tip opening displacement. **Mixed mode fracture:** Prediction of crack path and critical condition for crack extension under mixed mode loading using Maximum tensile stress, Minimum strain energy density and Maximum energy release rate criteria. **Experimental measurement of SIF and fracture toughness:** Measurement of plain strain fracture toughness (K_{IC}), Measurement of J_{IC}, Measurement of Critical COD. **Fatigue crack growth:** Mechanism of crack nucleation and growth under cyclic loading, Crack closure, Determination of life of a cracked solid using Paris-Erdogan law and its variants, Variable amplitude cyclic loading.
Learning Outcome	• Understanding of fundamental concepts behind the failure of material and mathematical foundation from mechanics. • Ability to understand how material fails and ability to prevent such failures. • Laboratory testing procedure of fracture parameters. Ability to predict the remaining life of the specimen/component.
Assessment Method	Class tests, quiz, Project (Case Studies), Mid-semester and End semester Examination.
Suggested Readings: **Text Books:**	

[1] T.L. Anderson, Fracture mechanics fundamentals and applications; CRC Press: Florida, Fourth Edition, 2017.

Reference Book

[1] C.T Sun and Z.H Jin, Fracture Mechanics; Elsevier: Oxford, First Edition, 2012.
[2] Prashant Kumar, Elements of Fracture Mechanics, Tata McGraw Hill, New Delhi, India, 2009.
[3] E. E. Gdoutos, Fracture Mechanics- An Introduction, Springer Netherlands,1990.
[4] D. Broek, Elementary Engineering Fracture Mechanics, Kluwer Academic Publishers, Dordrecht, 1986.
[5] M. Janssen, J. Zuidema and R.J.H Wanhill, Fracture Mechanics, Spon Press, New York, 2005.
[6] S. Suresh, Fatigue of Materials, Cambridge University Press, UK, 2003.