Mechanical System Design

Subject Name	Code	L-T-P	Credit	Contact Hours
Semester-1				
Vibrations	ME6L001	3-1-0	4	4
Applied Elasticity	ME6L052	3-1-0	4	4
DE 1		3-0-0	3	3
DE 2		3-0-0	3	3
DE 3		3-0-0	3	3
Mechanical Systems Simulation Laboratory-I	ME6P001	0-0-3	2	3
Vibration Laboratory	New code	0-0-3	2	3
Total			21	23
Semester-2				
Dynamics and Control of Mechanical Systems	ME6L051	3-1-0	4	4
Advanced Solid Mechanics	ME6L002	3-1-0	4	4
DE 4	Elective	3-0-0	3	3
DE 5	Elective	3-0-0	3	3
Mechanical Systems Simulation Laboratory-II	ME6P003	0-0-3	2	3
Design and Dynamics Laboratory	New code	0-0-3	2	3
Total			18	20
Semester-3				
Thesis Part – II	ME6D002		15	
Total			15	
Semester-4				
Thesis Part – III	ME6D003		15	
Total			15	
		Total Credits:	**69**	

***The students may opt for either an open elective or an elective from another department (with the consent of the teaching faculty and the faculty advisor) against any one of the department electives.**

Syllabus

Subject Code: ME 6L001 **Pre-Requisites: None**	**Name : Vibrations**	**CORE** **L – T – P :** **3 – 1 – 0**	**Credit : 4**

Introduction: Linear and non-linear vibration, Degrees of freedom, Modelling of vibrating mechanical systems, Derivation of equation of motion using Newton's and energy methods, Linearisation of equation of motion

Free Vibration of Single DOF Systems: Undamped vibration, Simple harmonic motion, Damped vibration with viscous and Coulomb damping.

Forced Vibration of Single DOF Systems: Forced harmonic excitation of undamped and damped systems, Base excitation problem and transmissibility, Rotating unbalance, Vibration under non-harmonic periodic forcing using Fourier series, Vibration with arbitrary aperiodic forcing using Convolution integral.

Vibration of Multi DOF Systems: Modelling of undamped and damped vibration of systems with two or more DOF, Eigenvalue problem and modal analysis for the free and forced vibrations, Orthogonality of normal modes, Dynamic vibration absorbers.

Vibration of Continuous Systems: Modelling of continuous system vibration, Longitudinal vibration of bars, Transverse vibration of strings and beams, Torsional vibration of circular shafts, Solution technique using variable separation method, Eigen frequencies and Eigen modes.

Energy and Computational Methods for Vibration: Rayleigh Quotient, Rayleigh-Ritz method, Matrix iteration method for multi DOF systems, Flexibility and stiffness influence coefficients.

Introduction to Vibration Measuring Instruments

Recommended Books:

Theory of Vibrations with Applications - William T. Thomson and Marie Dillon Dahleh (Pearson Education)
Mechanical Vibration – S. S. Rao (Prentice Hall)
Fundamentals of Vibrations - Leonard Meirovitch (Mcgraw-Hill)
Mechanical Vibrations: Theory and Applications - S. Graham Kelly (CL-Engineering)
Mechanical Vibration - William J. Palm (Wiley)
Principles of Vibration – B. H. Tongue (Oxford University Press)
Advanced Theory of Vibration - J. S. Rao (New Age International)
Vibration Testing: Theory and Practice - Kenneth G. McConnell and Paulo S. Varoto (Wiley)
Vibration problems in engineering- Stephen Timoshenko (Oxford)

Applied Elasticity (ME 6L052) **Pre-Requisites: None**	**CORE** **L – T – P – C** **3 – 1 – 0 – 4**

Introduction: Review of strength of materials and its limitations
Mathematical Preliminaries: Vector and tensor algebra, Tensor calculus, Indicial notation.
Deformation and Strain: Lagrangian and Eulerian descriptions of deformation, Deformation gradient tensor, Green-Lagrange and Eulerian strain tensors, Strain displacement relations in 3D, Infinitesimal strain tensor and rotation tensor, Principal strains, Strains in cylindrical coordinate systems, Strain compatibility equations.
Stress and Equilibrium: Surface traction vector, Cauchy stress tensor at a point, Cauchy stress formula, Principal Stresses, Hydrostatic and deviatoric stress tensors, Octahedral normal and shear stresses, First and second Piola-Kirchhoff stress tensors, Stress equilibrium equations in rectangular and polar coordinates.
Constitutive Relations: Generalized Hooke's law for linear elastic solids, Material symmetry concept, Elastic coefficient tensors for monoclinic, orthotropic, transversely isotropic and isotropic materials, Strain energy density function.
Balance Laws: Mass, momentum, angular momentum, and energy balance, Stress power
Boundary Value Problem: Formulation using field equations of elasticity, Stress and displacement based solution techniques, Navier equations and Beltrami-Michell equations
Planar Elastic Problems: Plane stress and plane strain problem solution using Airy's stress function, Stress functions for solving bending of straight beams, Torsion of prismatic shaft using Prandtl's stress function.
Problems in Polar Coordinates: Bending of curved beams, Axisymmetric problems, Stress concentration around a hole within a plate subjected to tension, Flamant's solution for elastic half space, Wedge problems.
Advanced Topics: Thermo-elasticity, Contact problems.

Recommended Books:
Theory of Elasticity – S. Timoshenko, and J.N. Goodier (McGraw Hill)
Elasticity in Engineering Mechanics – A.P. Boresi, and K.P. Chong (Wiley)
Elasticity: Theory, Applications and Numerics – M. H. Sadd (Academic Press Inc)
Applied Mechanics of Solids – A. Bower (CRC Press Inc)
Advanced Mechanics of Solids – L. S. Srinath (Tata McGraw-Hill)
The Linearized Theory of Elasticity – W. S. Slaughter (Springer)
Elasticity - J. R. Barber (Springer)

Subject Code: ME6P001	Name: Mechanical Systems Simulation Laboratory-I	L-T-P: 0-0-3	Credit: 2

Prerequisite(s): None

This laboratory is designed to introduce basic programming concepts using MATLAB.

Introduction to Basic Programming Concepts using MATLAB/Python: Matrices and Operators, Functions, Loops and conditional statements, File Input/Output, Plotting- 2D plots, Scatter, Quiver plot, Curve fitting etc.

Numerical Solution Techniques: Different solution techniques for various types of equations

Introduction to 3D Solid Modeling using Commercial CAD Softwares

Recommended Books:

Differential equations with MATLAB® – B.R. Hunt (Wiley).
An Introduction to MATLAB® Programming and Numerical Methods for Engineers – T. Siauw, and A. Bayen - (Academic Press)

Subject Code: to be assigned	Name: Vibration Laboratory	L-T-P: 0-0-3	Credit: 2

Prerequisite(s): None

1. Study of free and forced vibration of single DOF system
2. Vibration of simple and compound pendulums
3. Study of vibration isolation
4. Whirling of shaft experiment
5. Vibration absorber experiment
6. Damped torsional vibration experiment
7. Cantilever beam vibration study using FFT analyser and modal hammer
8. Study of mode shapes for beams using vibration shaker and function generator
9. Chladni plate modal pattern demonstration experiment
10. Study of transverse vibration of a taut string
11. Vibration measurement for different bearing and rotor faults using machine fault simulator
12. Dynamic balancing of rotating components.

Subject Code : ME 6L051 Pre-Requisites: None	Name : Dynamics and Control of Mechanical Systems	CORE L – T – P 3 – 1 – 0	Credit : 4

Introduction: Revisit to the history of development of mechanics from Galileo to Newton.
Newton-Eulerian Dynamics: Planar and spatial kinematics of rigid bodies in translating and rotating frames, Momentum and angular momentum of system of particles and rigid bodies, Planar and spatial kinetics, Euler's equation for general spatial motion of rigid body, Euler angles, Application to motion of symmetric tops and gyroscopes.
Analytical Dynamics: Generalized coordinates and generalized forces, Classification of constraints, d'Alembert's principle, Derivation of Lagrange's equation from d'Alembert's principle, Hamilton's principle for derivation of equation of motion and boundary conditions for various continuous systems (such as bar, string, beam)
Control: Modelling of control systems, Transfer function and block diagrams, Laplace transform, Time domain analysis, Steady state error and error constants, Routh-Hurwitz stability criterion, Root-locus diagram, Frequency domain analysis, Bode plot, Gain margin and phase margin, Nyquist plot and Nyquist stability criteria, PID controller design, Analysis of control systems in state space, Computer simulation through MATLAB SIMULINK®.

Recommended Books:

Methods of Analytical Dynamics - Leonard Meirovitch – Dover.
Classical Dynamics - Donald T. Greenwood – Dover.
Advanced Dynamics - Donald T. Greenwood – Cambridge University Press.
Analytical Mechanics - Herbert Goldstein - Addison Wesley.
Engineering Mechanics:Statics and Dynamics – I. H. Shames, Prentice-Hall of India.
Dynamics: Theory and Applications - T.R. Kane, David A. Levinson - McGraw-Hill.
System Dynamics - Katsuhiko Ogata - Pearson Education India.
Modern Control Engineering - Katsuhiko Ogata - Prentice Hall.
Control Systems Engineering - Norman S. Nise – Wiley.
Control System Design: An Introduction to State-Space Methods – B. Friedland – Dover.
Automatic Control Systems - Benjamin C. Kuo, Farid Golnaraghi – Wiley.
MATLAB® for Control Engineers - Katsuhiko Ogata - Prentice Hall.

Subject Code : ME6L002 Pre-Requisites: None	Name : Advanced Solid Mechanics	CORE L – T – P 3 – 1 – 0	Credit : 4

Yield Criteria: Different theories of failure for ductile and brittle materials.
Energy Methods: Generalised forces and displacements, Strain energy and complementary strain energy, Castigliano's first and second theorem, Principle of minimum potential.
Variational Formulation: Variational calculus, Derivation of governing equations and boundary conditions of beams and plates.
Bending of Beams: Axisymmetric bending, Shear centre for thin-wall beam sections, Bending of curved beams, beams on elastic foundation.
Torsion: Torsion of prismatic bars with circular and non-circular cross-sections, Wrapping function, Torsion of thin-walled closed section tubes.
Axisymmetric Problems: Thick walled cylinders, Stresses in composite cylinders with shrink fit, Stresses in rotating disks and cylinders.
Elastic Stability: General concepts of elastic stability for rigid and elastic systems, Beam-column problems, Eigen solution for buckling Euler columns with different end conditions, Rayleigh's energy method for Euler buckling.
Deformation of Plates: Classical plate theory (Love-Kirchhoff), Bending of thin plates in Cartesian and polar coordinates.
Contact Stress Problems: Contact between an elastic sphere and rigid plane; Contact between two frictionless cylindrical and spherical surfaces.

Recommended Books:
Advanced Mechanics of Materials - A.P. Boresi and R.J. Schmidt (Wiley)
Advanced Mechanics of Solids - L.S. Srinath (Tata McGraw Hill)
Advanced Mechanics of Materials - R. Solecki (Oxford University Press)
Strength of Materials and Structures - J. Case, L. Chilver and C.T.F. Ross (Butterworth-Heinemann)
Advanced Mechanics of Solids - Bruhns Otto T. (Springer)
Advanced Mechanics of Materials - R.D. Cook, W.C. Young (Prentice Hall)
Thin Plates and Shells- Theory, Analysis, and Applications - E. Ventsel, and T. Krauthammer (Marcel Dekker, Inc.)

Subject Code: ME6P002	Name: Design and Dynamic Laboratory	L-T-P: 0-0-3	Credit: 2

Prerequisite(s): None

1. Determination of material properties using various testing setups
2. Experiments of asymmetric bending of beams
3. Calculation of shear centre for thin-walled channel sections
4. Experiment on bending of curved beams
5. Study of buckling behaviour of different columns
6. Uni-axial and bi-axial testing of materials using UTM
7. Study of stress field pattern using Photo-elastic demonstration unit
8. Study of Journal bearing pressure profile
9. Study of multi-stage spur gear and epicyclic gear trains
10. Wear test on pin-on-disc apparatus
11. Use of PID controller for balancing of inverted pendulum and tank water level control
12. Use of Pressure, Temperature, Strain, Vibration and Sound sensors and actuators, respective data acquisition and processing.

Subject Code: ME6P003	Name: Mechanical Systems Simulation Laboratory-II	L-T-P: 0-0-3	Credit: 2

Prerequisite(s): None

Introduction to Symbolic Computation for Mechanical Engineering Problems

Computational Method: MATLAB/Python Functions for computational analysis, Solutions of initial and boundary value problems.

Commercial CAE Software: Static structural, thermal stress, modal, and transient dynamic analysis.

Control System: Modelling and analysis of dynamic control systems using MATLAB SIMULINK®.

Recommended Books:

Stephen J. Chapman - *MATLAB Programming for Engineers* (2008, Cengage Learning)
Timmy Siauw and Alexandre Bayen - *An Introduction to MATLAB® Programming and Numerical Methods for Engineers* (2015, Academic Press)