DEPARTMENT OF MECHANICAL ENGINEERING

COURSE STRUCTURE
&
DETAILED SYLLABUS
For
M.TECH

SPECIALIZATION
IN
MACHINE DESIGN & ANALYSIS

(Effective from 2016-17)

VEER SURENDRA SAI UNIVESITY OF TECHNOLOGY
BURLA, SAMBALPUR
PIN-768018

VEER SURENDRA SAI UNIVESITY OF TECHNOLOGY, BURLA
COURSE STRUCTURE FOR 2-YEARS M.Tech. DEGREE COURSE in
MECHANICAL ENGINEERING ON MACHINE DESIGN & ANALYSIS SPECIALISATION
TO BE EFFECTIVE FROM (2016-17)

MACHINE DESIGN & ANALYSIS

Code	1st Year (First Semester)	L-T-P	CR	1st Year (Second Semester)	L-T-P	CR
MME2101	Applied Elasticity and Plasticity	4-0-0	4	FEM in Engineering	4-0-0	4
MME2102	Advance d Mechanics of Solids	4-0-0	4	Composite Materials	4-0-0	4
MME2103	Mechanical Vibration Analysis	4-0-0	4	Experimental Stress Analysis	4-0-0	4
	Elective-I	4-0-0	4	Elective-III	4-0-0	4
	Elective-II	4-0-0	4	Elective-IV	4-0-0	4
Sessional				**Sessional**		
MME2191	Engg. Software Lab.	0-0-3	2	Design Project of Mechanical Systems	0-0-3	2
MME2192	Analysis and Design Engg.Lab.	0-0-3	2	Advanced Design Engg. Lab.	0-0-3	2
MME2193	Seminar – I	0-0-3	2	Seminar – II	0-0-3	2
MME2194	Comprehensive Viva-Voce - I		2	Comprehensive Viva-Voce – II		2
Total		**20-0-9**	**28**	**Total**	**20-0-9**	**28**

2nd Year (3rd Semester)		2nd Year (4th Semester)	
Dissertation Interim Evaluation	10	Dissertation Open Defence	5
Comprehensive Viva-Voce	3	Dissertation Evaluation	20
Seminar on Dissertation(100)	2		
Total	**15**	**Total**	**25**

Elective Subjects

Elective-I & Elective-II	**Elective-III & Elective-IV**
1.Automatic Control Systems	1.Advanced Theory of Mechanisms and Machines
2.CAD and Computer Graphics	2.Product Design
3.Fatigue,Creep and Fracture	3.Tribology
4.Theory Plates and Shells	4.Engineering Design Optimization
5.Robotics and Control	5.Mechatronics

APPLIED ELASTICITY AND PLASTICITY

COURSE OBJECTIVE

1. To impart knowledge of Principal stresses and strains
2. To develop analytical skills of solving problems using plain stress and plain strain.
3. To impart knowledge of engineering application of plasticity.

Module 1

1. **Introductions:** Elasticity, Fundamental Assumptions in Elementary Elasticity, Stress, Strain, Hooke's Law Plane Stress and Plane Strain. **[4]**
2. **Plane Stress and Plane Strain:** Stress and Strain at appoint, measurement of surface strains, equation of equilibrium and compatibility, boundary conditions, stress function. **[6]**

Module 2

3. **Two-dimensional problems in Rectangular Coordinates:** Solutions by Polynomials, Determination of displacements, Bending of a Cantilever Loaded at the end, Bending of a Beam by Uniform Loading. **[6]**

4. **Two-dimensional problems in Polar Coordinates:** General Equations in Polar Coordinate, Stress Distributions Symmetrical about an Axis, Pure bending of Curved Bars, Strain Components in Polar Coordinates, Displacements for Symmetrical Stress Distributions, Rotating Disks. **[8]**

Module 3

5. **Analysis of Stress and Strain in Three Dimensions:** Principal Stresses, Determination of the Principal Stresses and Maximum Shear Stresses, Stress Invariants. **[8]**

Module 4

6. **Introduction to Plasticity:** General Concept of Plasticity, Concept of Yielding and Elastic Failure, Yield Functions, Axioms and Postulates in Phenomenological Theory of Plasticity, Stress-Space Plasticity, Normality, Consistency conditions and Flow-rules, Associated and Non-Associated Plasticity, Perfect-Plasticity, Concept of hardening, Isotropic and Kinematic hardening, Constitutive relations for Elastoplasticity with hardening and perfect plasticity. **[8]**

Text Book:

1. S. P. Timoshenko and J. N. Goodier – Theory of Elasticity (Mc.Graw Hills)
2. O. Hoffman and G. Sachs – Theory of Plasticity (Mc.Graw Hills)

References:

1. A. I. Lurie- Theory of Elasticity (Springer)
2. J. Chakrabarty-Theory of Plasticity (Elsevier)

COURSE OUTCOME

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

1. Explain the concept of elasticity, and the difference between stress and strain
2. Explain the terms: isotropic, orthotropic and anisotropic, as applied to materials
3. Explain the terms: plane stress and plane strain
4. Conduct the transformation of plane stress or plane strain components using Mohr's circle, the method of eigenvalues and eigenvectors, the method of quadratic form of ellipsoids, and the method of stress or strain trajectories
5. Use the concepts of principal stress and principal strains

6. Use the basic tensor notations, the stress, strain and inertia tensors, and their reduction to principal axes
7. Apply the analytical procedures involved in strain gauge measurements, in particular the transformation equations
8. Solve basic problems in two-dimensional elasticity using Airy's stress function
9. Evaluate solutions of simple engineering problems using mechanics of material theories
10. Use basic stability and yield criteria for elasto-plastic materials
11. Apply basic concepts of elastic stability and buckling of elastic
12. Using finite difference approximations to solve elasticity problems governed by partial differential equations
13. Understand the importance of various yield criteria and material stability.

ADVANCED MECHANICS OF SOLIDS

COURSE OBJECTIVE

The primary objective of this course is to understand the mechanics of materials method and its application to and understanding of structural responses to various loading conditions. The structures (e.g., curved beams) and loading conditions (e.g., unsymmetric bending) considered are more advanced compared to an introductory course in mechanics of materials.

Module I

Analysis of stress and Strain: 3-D dimensional stress and strain: Analysis of Stresses and Strains in rectangular and polar coordinates, Generalized Hooke's law, Relation between elastic constants, Cauchy's formula, Principal stresses and principal strains, 3D Mohr's Circle, Octahedral Stresses, Hydrostatic and deviatoric stress, Differential equations of equilibrium, Plane stress and plane strain, compatibility conditions.

Theories of failure: Factors of safety in design. Ideally plastic in solids. Yield surfaces of Tresca and von Mices. prandtal renss and saint venant von mises equations. **[10]**

Module II

Energy Theorems: Strain energy due to axial load, bending, shear and torsion, Maxwell's reciprocal theorem, Energy methods in first and second theorems of Castigliano. Maxwell-Mohr integrals asymmetric bending of beams. analysis of helical springs by energy method. **[5]**

Unsymmetrical bending & Curved Beam Theory: Shear centers for sections with one axis of symmetry, shear center for any unsymmetrical Section, stress and deflection of beams subjected to unsymmetrical bending. Winkler Bach formula for circumferential stress – Limitations – Correction factors – Radial stress in curved beams – closed ring subjected to concentrated and uniform lads- stresses in chain links. **[5]**

Module III

Torsion: Torsion of a cylindrical bar of Circular cross Section; Saint-Venant's semi-inverse methods; Linear elastic solution; Prandtl elastic membrane (Soap-Film) Analogy; Narrow rectangular cross Section; Hallow thin wall torsion members, Multiply connected Cross section, Thin wall torsion members with restrained ends Axi-Symmetric Problems: Rotating Discs – Flat discs, Discs of uniform thickness, Discs of Uniform Strength, Rotating Cylinders. **[10]**

Module IV

Contact Stresses: Introduction, problem of determining contact stresses; Assumptions on which a solution for contact stresses is based; Expressions for principal stresses; Methods of computing contact stresses;

Deflection of bodies in point contact; Stresses for two bodies in contact over narrow rectangular area (Line contact), Loads normal to area; Stresses for two bodies in line contact. Normal and Tangent to contact area. **[5]**

Buckling of columns: Beam columns single concentrated load, number of concentrated loads, continuous lateral Load, end couple, couples at both ends triangular loads.

Beam on Elastic Foundations: General theory, infinite, semi infinite, finite beams classification of beams .Beam supported by equally spaced elastic elements. [**5]**

Text Book:

1. Advanced strength and applied elasticity by R.C. Ugural, S.K. Fenster, Elsevier.
2. Advanced mechanics of solids by Hugh ford Longmans.

Reference Book:

3. Strength of material by S.Timoshenko affiliated East-West press pvt.Ltd, .N. Delhi
4. Mechanics of Solids By L.S Srinath

COURSE OUTCOME

1. Methods of three-dimensional stress and strain analysis will be extended to allow the student to obtain solutions using analytical and/or numerical methods.
2. These will include the analyses of principal stresses and strains, three dimensional Mohr's circles, strain gauge experimentation and failure criteria.
3. In addition, this unit will focus on plastic deformation of solids, including the analysis of residual stresses and the collapse load of structures.
4. The responses of materials to fatigue and fracture, as well as their creep and viscoelastic behaviour, will also be explored.
5. Finally, this unit will provide a number of examples of experimental applications of solid mechanics analysis based on modern research techniques.

Mechanical Vibration Analysis

COURSE OBJECTIVE

At the end of this course the students will

1. fully understand and appreciate the importance of vibrations in mechanical design of machine parts that operate in vibratory conditions,
2. be able to obtain linear vibratory models of dynamic systems with changing complexities (SDOF, MDOF),
3. be able to write the differential equation of motion of vibratory systems,
4. be able to make free and forced (harmonic, periodic, non-periodic) vibration analysis of single and multi degree of freedom linear systems.

Module I:

1. Review of free and forced vibrations with and without damping. Hamilton’s Principle. **[5]**
2. Isolation: Theory of oscillation of single degree freedom system with application to Vibration isolation and vibration measurement. Vibration isolation and transmissibility; Un-damped vibration absorbers. **[5]**

Module II:

3. Multi degree of freedom system: Generalized coordinates and coordinate coupling; Orthogonality of modes, Free and forced vibration of multi-degree of freedom systems with and without viscous damping; Lagrange's equation; Holzer's method. Solution of Eigen value problem, transfer matrix and modal analysis. Multi-degree freedom system with application to measurement. Multiple degree of freedom systems with applications to dynamic vibration absorbers. Application of matrix to vibrational problems, General theory of small oscillation of conservative systems, principlal frequencies and modes. Introduction of Rayleigh and Rayleigh-ritz Methods. **[15]**

Module III:

4. Continuous System: Transverse vibration of a string, longitudinal vibration of a bar, torsional vibration of a shaft, transverse vibration of a beam. **[8]**

Module IV:

5. Vibration of membranes and plates, Lap lace Transforms and operational Methods. **[7]**

Text Book:

1. Mechanical Vibrations by G.K. Groover
2. Mechanical Vibration by W.T. Thompson

COURSE OUTCOME

1. Appreciating the need and importance of vibration analysis in mechanical design of machine parts that operate in vibratory conditions
2. Ability to analyze the mathematical model of a linear vibratory system to determine its response
3. Ability to obtain linear mathematical models of real life engineering systems
4. Ability to use Lagrange's equations for linear and nonlinear vibratory systems
5. Ability to determine vibratory responses of SDOF and MDOF systems to harmonic, periodic and non-periodic excitation
6. General notion on frequency and time response of vibratory systems

AUTOMATIC CONTROL SYSTEM

COURSE OBJECTIVE

1. To teach the fundamental concepts of Control systems and mathematical modeling of the
2. system
3. To study the concept of time response and frequency response of the system
4. To teach the basics of stability analysis of the system

Module-I
Closed loop & open loop systems; Linear & non-linear systems; Proportional, Derivative & integral controller; Laplace transform method; Transfer function & Block diagrams; Deriving transfer functions of physical systems; Block diagram reduction; Signal flow graphs; Construction of signal flow graphs from block diagram; Mason's gain formula. **[8]**

Module-II
First order systems; Second order systems; Higher order systems; Steady-state error & error constants; Routh stability criterion; Bode plot; Gain margin & Phase margin. **[10]**

Module-III
Root locus method; Nyquist criterion; Closed loop frequency response; M-circle & N-circle; Lag & lead compensation. **[10]**

Module-IV
State space analysis- State variables; State-space representation; State equations; Relationship between state equations & transfer functions; Characteristics equation; Eigen values & Eigen vectors; State diagram; Solution of state equation; State transition matrix & its properties; Transfer matrix. **[12]**

Text Book

1. Modern Control Engineering, Katsuhiko Ogata, Prentice Hall, India.

Control Systems Engineering, L. J. Nagrath & M. Gopal, Fifth Edition, New Age International Publishers

COURSE OUTCOME

2. Represent the mathematical model of a system
3. Determine the response of different order systems for various step inputs
4. Analyse the stability of the system

CAD & COMPUTER GRAPHICS

COURSE OBJECTIVE

1. To impart knowledge of topics addressing the impact of CAD and computer graphics in engineering design and analysis,
2. To develop the ability to establish the CAD techniques appropriate for mechanical engineering applications.
3. To apply knowledge of interdisciplinary nature of computer graphics, geometric modelling and engineering design in the wide variety of applications.
4. To know the different graphics software and packages
5. To develop knowledge of theoretical principles in optimization and artificial intelligence.

Module-I

1. Fundamental of CAD: The design process, Application of computers for design. Creating the manufacturing database. The design workstation, Graphics terminal, operator input devices, Plotters and other output devices. The CPU, Secondary storage. **[7]**

2. Geometric transformation of simple figures to different shapes by matrix method. **[3]**

Module-II

3. Computer Graphics Software: Configuration, Graphic packages, constructing the geometry, Transformation, Database structure and content. **[5]**

4. The benefits and cost of CAD: Principles of concurrent Engineering. Soft and hard prototyping, Workflow in Concurrent Engineering. Key factors influencing the success of Concurrent Engineering. **[5]**

Module-III

5. Graphic Workstation. Hardware of workstation, Advanced modelling techniques-Wire frame model, surface modelling, Solids modelling. Wire frame versus Solids modelling. **[7]**
6. Modelling facilities in solid modeller. **[3]**

Module-IV

7. Automated Drafting, Menu based drafting, Use of software for drawing/colour processing, Optimum Design: Optimum Design for Normal Specification, Optimum design for Redundant specification. **[7]**
8. Simple Engineering Design Problems. **[3]**

Text Books:
1. CAM: Computer Aided design & Manufacturing-MP Groover & E.W.Zimmer Jr. PHI. CAD.
2. CAD,CAM,CIM: P. Radhakrishana & S. Subramanyam – New Age International Publishers.
3. Optimization Theory & Applications: SS Rao, Wiely Eastern Ltd.

COURSE OUTCOMES

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

1. Explain the concepts and underlying theory of modeling and the usage of models in different engineering applications. Explain the benefits of a comprehensive and integrated CAD/CAM system.
2. Create accurate and precise geometry of complex engineering systems and use the geometric models in different engineering applications.
3. Compare the different types of modeling techniques and explain the central role solid models play in the successful completion of CAD/CAM-based product development.
4. Use and assess state-of-the-art CAD/CAM codes efficiently, effectively and intelligently in advanced engineering applications.

5. Develop algorithms for 2D and 3D geometric modeling.
6. Use current state-of-the-art CAD/CAM technology in research.
7. Extend CAD/CAM technology for research and development purposes, for example by developing CAD/CAM applications using open architecture solid modeling kernels.
8. Explain the basic concepts of CNC programming and machining.

Fatigue, Creep & Fracture

COURSE OBJECTIVE

1. Provide an understanding of the mechanics and micro-mechanisms of elastic and plastic deformation, creep, fracture, and fatigue failure, as applied to metals, ceramics, composites, thin film and biological materials.
2. Provide a thorough introduction to the principles of fracture mechanics.
3. Provide practical examples of the application of fracture mechanics to design and life prediction methods and reporting.
4. Provide a basis for the use of fractography as a diagnostic tool for structural failures.

Module-I

Fracture - Basic modes of fracture, Ductile & brittle fracture, Energy release rate, Grifth theory of brittle fracture, Crack resistance, Stable and unstable crack growth, Critical energy release rate, Irwin's theory of fracture in elastic-plastic materials, theories of linear elastic fracture mechanics, Anelastic deformation at crack tip, stress intensity function, Fracture toughness testing. **[10]**

Module-II

Fatigue - Fatigue and endurance limit, Fatigue under normal conditions, Relation between endurance limit & ultimate tensile strength, factor of safety in fatigue loading, stress concentration, controlling factors in fatigue design, design for fatigue fracture, Theories of strength and working stress. **[10]**

Module-III

Growth of fatigue crack, Sigmoidal curve, Paris-Erdogan law, Effect of overload, Basquin and Manson-Coffin relation, Damage accumulation and the wholler curve. **[10]**

Module-IV

Creep - Low temperature properties, High temperature properties, Temperature and Creep stress-strain properties, Creep-time curve, Creep-stress-time-temperature relation for simple tension.

Mechanics of creep - Creep in tension, Creep in bending, Creep in torsion, Creep buckling, Member subjected to creep and combined stresses. **[10]**

Text books:

1. Fracture Mechanics- T L Anderson (CRC press)
2. Mechanical Behavior of Engineering Material- J Marin (PHI)
3. Mechanical Metallurgy – George E. Dieter (Mc Graw-Hill)

COURSE OUTCOME

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

1. Distinguish between ductile and brittle fracture.
2. Describe a stress concentrator (also called stress raiser) and the danger it represents.
3. Distinguish between the resistance to deformation and to fracture, and name their units.
4. Explain why hard materials are more brittle than soft metals.
5. Explain why ceramics are unreliable in tensile stresses.
6. Describe fatigue, its mechanism, its consequences and what can be done to the material in order to improve fatigue resistance.
7. Measure and describe creep and name the important engineering situations where it plays a major role.

THEOR Y OF PLATES AND SHELLS

COURSE OBJECTIVE

1. Introduce students to the classical structural mechanics approximations of Membrane, Plate and Shell theories.
2. Use energy formulations to demonstrate the consistent derivation of approximate boundary conditions and edge effects.
3. Demonstrate the analysis tools necessary to describe static, dynamic and non-linear motions.
4. Demonstrate the approximation of the classical formulations using numerical approximation techniques.

Module-I

1. Introduction: Assumptions in the theory of thin plates, Pure bending of Plates, Relations between bending moments and curvature, Particular cases of pure bending of rectangular plates, Cylindrical bending, Strain energy in pure bending of plates in Cartesian and polar co-ordinates, Limitations. **[7]**

2. Laterally Loaded Rectangular Plates: Differential equation of plates, Boundary conditions, Navier solution for simply supported plates subjected to uniformly distributed load and point load, Levy's method of solution for plates, Simply supported plates with moments distributed along the edges, Approximate Methods. **[10]**

Module-II

3. Effect of transverse shear deformation: plates of variable thickness, Anisotropic plates, thick plates, orthotropic plates and grids, Large Deflection theory. **[6]**

Module-III

4. Deformation of Shells without Bending: Definitions and notation, shells in the form of a surface of revolution, displacements, membrane theory of cylindrical shells, the use of stress function in calculating membrane forces of shells. **[8]**

Module-IV

5. General Theory of Cylindrical Shells: A circular cylindrical shell loaded symmetrically with respect to its axis, symmetrical deformation, pressure vessels, cylindrical tanks, general case of deformation, the use of a strain and stress function, stress analysis of cylindrical roof shells. **[9]**

TEXT BOOK

1. Theory of Plates and Shells by Stephen P. Timoshenko, Sergius Woinowsky-Krieger (McGraw- Hill)
2. Thin Plates and Shells: Theory: Analysis, and Applications by Eduard Ventsel, Theodor Krauthammer (CRC)

REFERENCES

1. Mechanics of Laminated Composite Plates and Shells: Theory and Analysis by J. N. Reddy (CRC)

COURSE OUTCOMES

On completion of the course, students can:

1. Apply the structural mechanics approximations of membrane, plates and shells.
2. Derive simple modifications to the membrane plate and shell theories.
3. Use analysis to determine the static, dynamic, and non-linear motion of membrane, plate and shell structures.
4. Compute numerical approximations.

ROBOTICS AND CONTROL

COURSE OBJECTIVE

1. To develop the student's knowledge in various robot structures and their workspace.
2. To develop student's skills in performing spatial transformations associated with rigid body motions.
3. To develop student's skills in perform kinematics analysis of robot systems.
4. To provide the student with knowledge of the singularity issues associated with the operation of robotic systems.
5. To provide the student with some knowledge and analysis skills associated with trajectory planning.
6. To provide the student with some knowledge and skills associated with robot control.

Module I

1.Introduction: Definition, Structure, Classification and Specifications of Robots, Industrial Robots. **[2]**

2.Robot Elements and Control: Manipulators, Drives, Sensors, End Effectors, Configuration, Force/Torque Relationship, Trajectory Planning, Position Control, Feedback System, Digital Control **[5]**

Module II

3.Modeling of Robots: Coordinate Frames, Mapping and Transformation; Direct Kinematic Model; Inverse Kinematics; Manipulator Differential Motion; Static Analysis; Jacobian **[10]**

Module III

4.Manipulator Dynamics: Acceleration of a rigid body, mass distribution, Newtons equation, iterative Newton Euler dynamic formulation, Lagrangian formulation of manipulator dynamics, Bond graph modeling of manipulators, Trajectory Planning. **[10]**

5.Linear and Non Linear Control of Manipulators: Control law partitioning, trajectory following control, multi input multi output control systems, Cartesian based control scheme. **[10]**

Module IV

6.Force Control of manipulators: hybrid position/force control **[3]**

7. Robot Programming: Robot Programming for Manufacturing and Other Applications, Robot Integration with CAD and CAM. **(2)**

Text Book:

1. Craig John J., “Introduction to robotics: Mechanics & Control”, Addison- Wesley, 1986.
2. Niku Saeed B., Introduction to Robotics: Analysis, Systems, Applications, PHI, New Delhi, 2001.

COURSE OUTCOMES

1. Students will demonstrate knowledge of the relationship between mechanical structures of industrial robots and their operational workspace characteristics.

2. Students will demonstrate an ability to apply spatial transformation to obtain forward kinematics equation of robot manipulators.

3. Students will demonstrate an ability to solve inverse kinematics of simple robot manipulators.

4. Students will demonstrate an ability to obtain the Jacobian matrix and use it to identify singularities.

5. Students will demonstrate an ability to generate joint trajectory for motion planning.

6. Students will demonstrate knowledge of robot controllers.

FINITE ELEMENT METHODS IN ENGINEERING

COURSE OBJECTIVES

This course will develop your Technical Competence capability. Upon successful completion of this course, student should:

1. Possess a good understanding of the theoretical basis of the weighted residual Finite Element Method.
2. Be able to implement the Galerkin residual weak formulation into the Finite Element Method for the solution of Ordinary and Partial Differential Equations, using mathematical software such as Maple.
3. Be able to use the commercial Finite Element package ANSYS to build Finite Element models and solve a selected range of engineering problems.
4. Be able to validate a Finite Element model using a range of techniques.
5. Be able to communicate effectively in writing to report (both textually and graphically) the method used, the implementation and the numerical results obtained.
6. Be able to discuss the accuracy of the Finite Element solutions.

Module 1

1. **Introduction:** Role of the Computer, General Steps of the Finite Element Method, Applications of the Finite Element Method, Advantages of the Finite Element Method. **[2]**
2. **Introduction to the Stiffness (Displacement) Method:** Definition of the Stiffness Matrix, Derivation of the Stiffness Matrix for a Spring Element, Example of a Spring Assemblage, Assembling the Total Stiffness Matrix by Superposition (Direct Stiffness Method),Boundary Conditions, Potential Energy Approach to Derive Spring Element Equations. **[4]**
3. **Development of Truss Equations:** Derivation of the Stiffness Matrix for a Bar Element in Local Coordinates, Selecting Approximation Functions for Displacements, Transformation of Vectors in Two Dimensions, Global Stiffness Matrix, Computation of Stress for a Bar in the x-y Plane, Solution of a Plane Truss. **[4]**

Module 2

4. **Energy Approach to Derive Bar Element Equations:** Potential Energy Approach to Derive Bar Element Equations, Comparison of Finite Element Solution to Exact Solution for Bar, Galerkin’s Residual Method and Its Use to Derive the One-Dimensional Bar Element Equations, Other Residual Methods and Their Application to a One-Dimensional. **[5]**
5. **Development of Beam Equations:** Derivation of the Beam Stiffness matrices, Distributed Loading, Potential Energy Approach to Derive Beam Element Equations, Galerkin’s Method for Deriving Beam Element Equations. **[5]**

Module 3

6. **Development of the Plane Stress and Plane Strain Stiffness Equations:** Basic Concepts of Plane Stress and Plane Strain, Derivation of the Constant-Strain Triangular Element Stiffness Matrix and Equations, Treatment of Body and Surface Forces. **[3]**
7. **Development of the Linear-Strain Triangle Equations:** Derivation of the Linear-Strain Triangular Element Stiffness Matrix and Equations. **[3]**
8. **Axisymmetric Elements:** Derivation of the Stiffness Matrix, Solution of an Axisymmetric Pressure Vessel, Applications of Axisymmetric Elements. **[4]**

Module 4

9. **Isoparametric Formulation:** Isoparametric Formulation of the Bar Element Stiffness Matrix, Rectangular Plane Stress Element, Gaussian and Newton-Cotes Quadrature (Numerical Integration), Evaluation of the Stiffness Matrix and Stress Matrix by Gaussian Quadrature. **[5]**

10. Three-Dimensional Stress Analysis: Three-Dimensional Stress and Strain, Tetrahedral Element. **(2)**

11. Plate Bending Element: Basic Concepts of Plate Bending, Derivation of a Plate Bending Element Stiffness Matrix and Equations. **[3]**

Text Books:

1. A First Course in the Finite Element Method- Daryl L. Logan, Thomson
2. Introduction to finite element method – Abel and Desal, EWP

References:

1. The Finite Element method in Engineering Science – O.C. Zienkiwiecs, TMH
2. Introduction to the finite element method-J. N. Reddy, Mc Graw Hill

COURSE OUTCOMES

1. Apply variation principles to develop advanced finite element models for various problems in solids.
2. Develop and solve finite models in nonlinear mechanics including geometric and material nonlinearities.
3. Solve advanced problems in solid mechanics using general-purpose finite element codes for two- and three-dimensional solid elasticity and plate bending problems.
4. Use various structured and unstructured mesh generation techniques for complex geometries.
5. Analyze and evaluate the solution of finite element codes.
6. Code advanced finite element programs with minimum extra training.
7. Apply the method to advanced problems in their specific field of study.

COMPOSITE MATERIALS

COURSE OBJECTIVES

1. introduce students to the concepts of modern composite materials; and
2. Equip them with knowledge on how to fabricate and carry out standard mechanical test on composites.
3. To make student understand the basic stress and strain relations in composite materials

Module-I

Introduction – Definition & classification of composites; Reinforcing fibers-Types, Characteristics & Selection; Natural fibers, Boron; Carbon; Ceramic; Glass; Armids; Particulate fillers; Matrices-Polymer; Graphite; Ceramic & Metal matrices; Fiber surface treatments; Fillers & additives; Fiber content; Short & continuous fiber reinforced composites. **[8]**

Module-II

Processing – Pultrusion; Filament winding; Pre-page technology; Injection & compression moulding; Bag moulding; Resin transfer moulding; Other manufacturing processes; Processing of MMC- Diffusion bonding; Stir casting; Squeeze casting. **[8]**

Module-III

Mechanics – Rule of mixture; Volume & mass fractions; Density & void content; Stress-strain relations for anisotropic materials; Generallized Hook's law; Stiffenesses, Compliances & engineering constants for orthotropic materials; Stress-strain relations for plane stress in orthotropic materials; Stress-strain relations for a lamina; Characteristics of fiber reinforced lamina. **[12]**

Module-IV

Analysis – Classical lamination theory; Stress analysis of composite laminates; Failure predictions – Maximum stress theory; Maximum strain theory; Tsai-Hill theory; Modes of failure of composites; First ply failure; Partial ply failure; Total ply failure. **[12]**

Text Book

1. Mechanics of composite materials, R. M. Jones, Mc Graw Hill Book Co.
2. Mechanics of composite materials & structures, M Mukhopadhay, Universities Press.
3. Fiber-Reinforced composite materials, Manufacturing & Design, P. K. Mallick, Marcel Dekken, Inc. New York & Basel.

COURSE OUTCOMES

Upon successful completion of this course, the student will be able to:

1. (Knowledge based) identify and explain the types of composite materials and their characteristic features;
2. understand the differences in the strengthening mechanism of composite and its corresponding effect on performance and application;
3. understand and explain the methods employed in composite fabrication;
4. Appreciate the theoretical basis of the experimental techniques utilized for failure mode of composites.
5. (Skills) develop expertise on the applicable engineering design of composite;
6. Learn simple micromechanics and failure modes of composites.

EXPERIMENTAL STRESS ANALYSIS

COURSE OBJECTIVE

1. To gain understanding of advanced concepts of 3D stress and strain by analysis of solids and structures
2. To study engineering properties of materials, force-deformation, and stress-strain relationship
3. To learn advanced principles of equilibrium, compatibility, and force-deformation relationship, and principle of superposition in linear solids and structures
4. To analyze problems related to stresses in composite tubes, thermo-elastic stress and strain, buckling, and
5. Asymmetric bending etc.

Module-I

Electrical Wire Resistance Strain Gauges: Strain sensitivity, strain gauge construction, temperature effects in bonded strain gauges. Gauge factor and gauge sensitivities. Determination of actual strain. Measurement of stress by a strain gauge, stress gauge, strain gauge Rosette. **[7]**

Measuring Circuits: The potentiometer circuit, circuit sensitivity of potentiometer, Wheatstone bridge circuit, Null-balance bridge, strain gauge applications. **[5]**

Module-II

Moiré Fringe Method: Moiré method, geometry of moiré fringe, advantages and limitations of moiré method. **[5]**

Module-III

Photoelasticity: Introduction, basic principle, stress and strain optic law, plane polariscope, circular polariscope, white light illumination. **[8]**

Analysis Of Photoelastic Data: Materials and properties of material for photoelastic models, stress loci, fractional fringe orders, methods of compensation, calibration techniques, the frozen stress method, Reflection polariscope, separation of principal stresses. **[10]**

Module-IV

Brittle Coating Method: Brittle coating, calibration of coating, application of failure theory to brittle coating, advantages and limitations. **[5]**

Text Books:

1. J.W. Dally and W.F. Riley, "*Experimental stress Analysis"*, McGraw Hill, 1991.
2. Durelli, Augusto J., and William Franklin Riley. " *Introduction to photomechanics*. Prentice-Hall, 1965.

COURSE OUTCOMES

After taking this course students should be able to:

1. Solve the advanced practical problems related to the theory of elasticity, concepts of stress and strain,
2. Strength and stiffness, deformations and displacements, strain energy, and load carrying capacity.
3. Propose materials and structural elements to the analysis of complex structures
4. Identify, formulate and solve the structural problems using a range of analytical methods.

ADVANCED THEORY OF MECHANISM & MACHINES

COURSE OBJECTIVE

The course has been designed to cover the basic concepts of kinematic aspects of mechanical machines and major parts used in running of the machines and

1. The students will understand the basic concepts of machines and able to understand constructional and working features of important machine elements.
2. The students should be able to understand various parts involved in kinematics of machines for different applications.
3. The students shall also be able to understand requirements of basic machine parts which would help them to understand the design aspects of the machine parts.

Module-I **[8]**
Review of determination of velocity & acceleration of points & links in mechanisms – Analytical & graphical methods; Synthesis of Mechanisms - Function generation; Overlay's method; Congnate linkages; Two position & three position synthesis of 4-bar linkages & slider crank mechanisms; Coupler curve synthesis; Intermittent rotary motion-Geneva mechanism.

Module-II **[12]**
Static & Dynamic Force Analysis – Forces, Couples, Conditions of equilibrium – Free body diagram; Analysis of 4-bar linkages & slider crank mechanisms; Spur, Helical & Bevel gear force analysis; Static force analysis with friction; Dynamic force analysis – Centroid & Centre of mass; Moment of inertia; D' Alembert's principle; Rotation about a fixed centre; Dynamic analysis of 4-bar mechanism.

Module-III **[10]**
Balancing – Primary balancing, Secondary balancing, Balancing of 2-cylinder & multi-cylinder engines, V-engines.
Gyroscope – Motion of a rigid body in 3-dimensions; Rigid body in spheric motion; Euller's equation; Euller's modified equation; Simple precession of a symmetrical rotor.

Module-IV **[10]**
Analysis of Cams – Basic curves; Cam size determination; Cam profile determination-Analytical & graphical methods; Advanced cam curves; Analytical cam design.
Cam Dynamics – Response of undamped cam mechanisms; Follower response-Phase plane method; Numerical method; Jump & Cross-over shock.

Text Book

1. Theory of Machines & Mechanisms, J. E. Shigley, McGraw-Hill Publication.
2. Theory of Mechanisms & Machines, Ghose & Mallick, East-West Press.

COURSE OUTCOMES

3. Familiarity with common mechanisms used in machines and everyday life.
4. Ability to calculate mobility (number of degrees-of-freedom) and enumerate rigid links and types of joints within mechanisms.
5. Ability to conduct a complete (translational and rotational) velocity, acceleration analysis of the mechanism and to understand steering mechanism and the importance of universal (Hooke's) joint
6. Helps to understand various cam motion profiles and follower mechanism , their classification and design based on the prescribed follower motion (SHM , constant velocity and acceleration)
7. At the end of this unit students are able to understand gear mechanism classification and to become familiar with gear standardization and specification in design.
8. To understand importance gear trains and their practical applications.
9. At the end of this unit, the students should be able to understand: Uses and advantages of belt drives Types and their nomenclature, Relationship between belt tensions commonly used design parameters.

PRODUCT DESIGN

COURSE OBJECTIVE

The focus of Product Design is

1. Integration of the marketing, design, and manufacturing functions of the firm in creating a new product. The course is intended to provide you with the following benefits:
2. Competence with a set of tools and methods for product design and development.
3. Confidence in your own abilities to create a new product.
4. Awareness of the role of multiple functions in creating a new product (e.g. marketing, finance, industrial design, engineering, production).
5. Ability to coordinate multiple, interdisciplinary tasks in order to achieve a common objective.
6. Reinforcement of specific knowledge from other courses through practice and reflection in an action-oriented setting.
7. Enhanced team working skills.

Module-I

The Product-scope, types of product Design requirements-functional, operating, portability, shipment, installation, use maintenance, appearance & cost. **[8]**

Module-II

Design factors-functions, attributes, circumstances, Resources, restraints, and uncertainly Design logic. **[6]**
Design method-stages, investigation product design, development test. **[6]**

Module-III

Design for function, Designing for use, design for appearance, Design for production. **[5]**
Standardization – Effects of standard, quality, reliability, Interchangeability, variety reduction. **[5]**

Module-IV

Value Engineering – Value analysis, Analysis of function. **[5]**
Material selection, properties, cost manufacturing process. **[5]**

Text Books:

1. Engg. Product Design – W.D. Cain (Business Book Ltd.)
2. Value Engineering: Concepts, Techniques and Applications By Anil Kumar Mukhopadhyaya (SAGE)

COURSE OUTCOMES

1. Articulate, critique and apply aesthetic principles in both 2D and 3D compositions.
2. Understand and apply principles of creativity to develop original and useful ideas.
3. Understand how to recognize and evaluate creative ideas.
4. Recognize sparks and blocks to creativity.
5. Understand human needs, wants and desires as they relate to products, systems and services.
6. Understand the basics of manufacturing processes and related materials.
7. Understand basic mechanical principles, devices and tools, and the physics that make them work.
8. Communicate ideas effectively both verbally and visually.
9. Apply basic business practices as they relate to Industrial Design.
10. Understand the relationship of business, technology, and human values.
11. Discuss the basics of design history and identify contemporary issues on a global scale.
12. Synthesize and apply learning outcomes in the context of a diverse range of design projects.
13. To manage time and resources effectively both personally and organizationally.
14. Understand group dynamics and how to be a productive member of a team.
15. Understands the global nature of society and appreciates the value of unique points of view.

TRIBOLOGY

COURSE OBJECTIVE

Design of surfaces in contact is a critical problem for mechanical engineering. This is an interdisciplinary course which deals with fundamentals of surface contact, friction, wear and lubrication.

Module-I

1. **INTRODUCTION:** Defining Tribology, Tribology in Design - Mechanical design of oil seals and gasket - Tribological design of oil seals and gasket, Tribology in Industry (Maintenance), Defining Lubrication, Basic Modes of Lubrication, Properties of Lubricants, Lubricant Additives, Defining Bearing Terminology - Sliding contact bearings - Rolling contact bearings, Comparison between Sliding and Rolling Contact Bearings. **[4]**

2. FRICTION and WEAR: Friction - Laws of friction - Friction classification - Causes of friction, Theories of Dry Friction, Friction Measurement, Stick-Slip Motion and Friction Instabilities, Wear - Wear classification - Wear between solids - Wear between solid and liquid - Factors affecting wear - Measurement of wear, Theories of Wear, Approaches to Friction Control and Wear Prevention, Boundary Lubrication, Bearing Materials and Bearing Construction. **[4]**

Module-II

3. **LUBRICATION of BEARINGS:** Mechanics of Fluid Flow - Theory of hydrodynamic lubrication - Mechanism of pressure development in oil film, Two Dimensional Reynolds's Equation and its Limitations, Idealized Bearings, Infinitely Long Plane Fixed Sliders, Infinitely Long Plane Pivoted Sliders, Infinitely Long Journal Bearings, Infinitely Short Journal Bearings, Designing Journal Bearing - Sommerfeld number - Raimondi and Boyd method - Petroff's Solution - Parameters of bearing design - Unit pressure - Temperature rise - Length to diameter ratio - Radial clearance - Minimum oil-film thickness. **[7]**

4. **HYDRODYNAMIC THRUST BEARING:** Introduction - Flat plate thrust bearing - Tilting pad thrust bearing, Pressure Equation - Flat plate thrust bearing - Tilting pad thrust bearing, Load - Flat plate thrust bearing - Tilting pad thrust bearing, Center of Pressure - Flat plate thrust bearing - Tilting pad thrust bearing, Friction - Flat plate thrust bearing - Tilting pad thrust bearing. **[5]**

Module-III

5. **HYDROSTATIC and SQUEEZE FILM LUBRICATION:** Hydrostatic Lubrication - Basic concept - Advantages and limitations - Viscous flow through rectangular slot - Load carrying capacity and flow requirement - Energy losses - Optimum design, Squeeze Film Lubrication - Basic concept - Squeeze action between circular and rectangular plates - Squeeze action under variable and alternating loads, Application to journal bearings, Piston Pin Lubrications. **[6]**

6. ELASTO-HYDRODYNAMIC LUBRICATION: Principles and Applications, Pressure viscosity term in Reynolds's equation, Hertz's Theory, Ertel-Grubin equation, Lubrication of spheres, Gear teeth bearings, Rolling element bearings. **[5]**

Module-IV

7. GAS (AIR-) LUBRICATED BEARINGS: Introduction, Merits, Demerits and Applications, Tilting pad bearings, Magnetic recording discs with flying head, Hydrostatic bearings with air lubrication, Hydrodynamic bearings with air lubrication, Thrust bearings with air lubrication **[6]**

8. TRIBOLOGICAL ASPECTS of ROLLING MOTION: The mechanics of tyre-road interactions, Road grip and rolling resistance, Tribological aspects of wheel on rail contact. **[3]**

Text Book:
1. Lubrication of bearing by E. I. Radzimogky (John Willey)
2. Lubrication in Practice by W. L. Robertson (CRC)

COURSE OUTCOME

The focus of Tribology & Lubrication is the fundamentals of interfacial contact, adhesion, friction, wear and lubrication. By the end of the course student should:

1. Have a knowledge of surface topography and know how to model a rough engineering surface;
2. Have a clear overall picture about the basics of tribology and related sciences, theoretical background about processes in tribological system, mechanisms and forms of interaction of friction surfaces;
3. Be familiar with adhesion theories and the effect of adhesion on friction and wear;
4. Have a mastery of the friction/lubrication mechanisms and know how to apply them to the practical engineering problem;
5. Know the methods to reduce the friction for engineering surface

ENGINEERING DESIGN OPTIMIZATION

COURSE OBJECTIVE

The course aims at integrating traditional design methodologies with concepts and techniques of modern optimization theory and practice. In the course the student will learn to create an appropriate mathematical description (a simulation model) of the design problem, to formulate the optimization problem and finally to use numerical optimization techniques and computer support tools in order to solve the problem.

Module 1

Introduction: Introduction to design and specifically system design, Morphology of design with a flow chart, Very brief discussion on market analysis, profit, time value of money, an example of discounted cash flow technique, Concept of workable design, practical example on workable system and optimal design. **[8]**

Module 2

System Simulation: Classification, Successive substitution method – examples, Newton Raphson method - one unknown – examples, Newton Raphson method - multiple unknowns – examples, Gauss Seidel method – examples, Rudiments of finite difference method for partial differential equations, with an example. **[8]**

Module 3

Regression and Curve Fitting: Need for regression in simulation and optimization, Concept of best fit and exact fit, Exact fit - Lagrange interpolation, Newton's divided difference – examples, Least square regression - theory, examples from linear regression with one and more unknowns – examples, Power law forms – examples, Gauss Newton method for non-linear least squares regression - examples. **[8]**

Module 4

Optimization: Introduction, Formulation of optimization problems – examples, Calculus techniques – Lagrange multiplier method – proof, examples, Search methods – Concept of interval of uncertainty, reduction ratio, reduction ratios of simple search techniques like exhaustive search, dichotomous search, Fibonacci search and Golden section search – numerical examples, Method of steepest ascent/ steepest descent, conjugate gradient method – examples, Geometric programming – examples, Dynamic programming – examples, Linear programming – two variable problem –graphical solution, New generation optimization techniques – Genetic algorithm and simulated annealing – examples, Introduction to Bayesian framework for optimization- examples. **[8]**

Text Book:

1. Optimization for engineering design - algorithms and examples, K. Deb, Prentice Hall

2. Introduction to optimum design, J. S. Arora, Mc Graw Hill

COURSE OUTCOMES

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

1. Explain the concept of the existence and uniqueness of an optimal solution.
2. Understand basic optimization methods for a single variable.
3. Understand the use of applying various types of constraints to numerical optimization.
4. Apply response surface methods to model complex engineering systems.
5. Apply design of experiments techniques to model a design space.
6. Solve numerical optimization problems of n-variables with constraints.
7. Use of a practical software package to solve typical engineering problems.
8. Model a realistic engineering design optimization problem as a semester project.

MECHATRONICS

COURSE OBJEJCTIVE

1. To develop an ability to identify, formulate, and solve engineering problems.
2. Be able to model and analyze electrical and mechanical systems and their interconnection.
3. To develop an ability to design a system, component, or process to meet desired needs within realistic constraints.
4. Be able to integrate mechanical, electronics, control and computer engineering in the design of mechatronics systems.
5. Be able to do the complete design, building, interfacing and actuation of a mechatronic system for a set of specifications.

Module I

1.Introduction: Definition of mechatronics, measurement system, control systems, microprocessor based controllers, mechatronics approach. [**2]**

2.Sensors and Transducers: Sensors and transducers, performance terminology, photoelectric transducers, flow transducers, optical sensors and transducers, semiconductor lasers, selection of sensors, mechanical / electrical switches, inputting data by switches. **[7]**

Module II

3. Actuators: Actuation systems, pneumatic and hydraulic systems, process control valves, rotary actuators, mechanical actuation systems, electrical actuation systems. **[5]**

4Signal Conditioning: Signal conditioning, filtering digital signal, multiplexers, data acquisition, digital signal processing, pulse modulation, data presentation systems. **[4]**

Module III

5.Microprocessors and Microcontrollers: Microcomputer structure, microcontrollers, applications, programmable logic controllers. **[8]**

6.Modeling and System Response: Mathematical models, mechanical, electrical, hydraulic and thermal systems, dynamic response of systems, transfer function and frequency response, closed loop controllers.**[8]**

Module IV

7.Design and Mechatronics: Input/output systems, computer based modular design, system validation, remote monitoring and control, designing, possible design solutions, detailed case studies of mechatronic systems used in photocopier, automobile, robots. **[6]**

Text Book:

3. Bolton, W., “Mechatronics”, Longman, 1999.
4. Bolton, W., “Mechatronics: A Multidisciplinary Approach”, 4th Ed., Prentice Hall, 2009.
5. Mahalik, N., “Principles, Concept and Applications: Mechatronics”, Tata McGraw, 2003.

COURSE OUTCOMES

1. Ability to design and calculate mechanical designs.
2. Ability to design and calculate electronic circuits.
3. Ability to develop software for intelligent products.
4. Ability to model and build mechatronic systems and implement these systems.
5. Ability to apply technological knowledge and theories for the development of new products.
6. Specialized knowledge within either of the profiles: Mechanical engg, Electronic engg or embedded engg.
7. Ability to carry out development projects independently and in teams.

ENGINEERING SOFTWARE LABORATORY

1. Computation & programming in Fortran & C, C++.
2. Object oriented programming, use of packages.

ANALYSIS AND DESGN ENGG. LABORATORY

1. Experiment of Universal Testing Machine.
2. Experiment on Fatigue machine
3. Experiment on NDT set up
4. Experiment on Damped vibration system
5. Experiment on vibration set up with modulated frequency of Excitation.

DESIGN PROJECT OF MECHANICAL SYSTEM

ADVANCED DESIGN ENGG. LABORATORY

1. Measurement of strain by strain gauge
2. Measurement of component strain by using strain rosette

3. Analysis of stress by photo elasticity method
4. Experiment on vibration meter.