AUPE3003 COMPUTATIONAL THEORY ON SOLID MECHANICS (3-0-0)

Course Objectives:
1. To provide a comprehensive understanding of the stiffness method for analyzing structures.
2. To expose students to non-linear behavior of materials and geometric nonlinearities.
3. To apply Finite Element Methods for structural mechanics problems.
4. To use energy methods for evaluating deformation in structural members.

Module-I Stiffness Method (08 Hours)

Overview of structural analysis using stiffness method. Types of structures: trusses, beams, and plane frames. Internal forces: axial, shear, bending moment, torsion. Derivation of element stiffness matrices for: Truss element, Beam element (with bending), Plane frame element (combined bending and axial). Assembly of global stiffness matrix. Application of boundary conditions. Solving for nodal displacements and reaction forces. Examples using matrix formulation.

Module-II Special Topics in Stiffness Methods (08 Hours)

Effect of pre-strain and initial stress on structural stiffness. Temperature effects on structural deformations. Support deformation and its influence on global stiffness. Application of symmetry and anti-symmetry in structural analysis. Elastic foundation support modelling. Coupled axial and flexural behavior in members. Composite structural elements: laminated beam and frame analysis. Introduction to shear deformation theories.

Module-III Nonlinear Problems in Solid Mechanics (08 Hours)

Introduction to nonlinearity: Geometric nonlinearity (large displacements and rotations), Material nonlinearity (plasticity, creep, viscoelasticity). Linear vs. nonlinear load- displacement response. Incremental and iterative solution methods. Newton-Raphson method: basic algorithm, convergence criteria. Modified Newton-Raphson and arc-length method (overview). Case studies on beam-column buckling and elasto-plastic behaviour.

Module-IV Finite Element Method (FEM) (09 Hours)

Continuum mechanics review: Stress and strain tensors, Hooke's law for isotropic materials. Plane stress and plane strain assumptions. FEM formulation for: 1D bar element, 1D beam element, 2D Constant Strain Triangle (CST) element. Shape functions and interpolation. Element stiffness matrix derivation. Boundary conditions and assembly procedures. Compatibility and convergence requirements. Meshing and numerical integration (Gauss quadrature – brief).

Module-V Energy Methods (8 Hours)

Principle of virtual work and minimum potential energy. Derivation of equilibrium equations using energy principles. Castigliano's First and Second Theorems. Application to statically indeterminate structures. Evaluation of strain energy due to axial, bending, shear, and torsion loads. Energy-based deflection analysis. Structural optimization concepts using energy principles (brief).

Course Outcomes (COs):

On successful completion of this course, students will be able to:

CO1: Develop stiffness matrices for trusses, beams, and frames.
CO2: Analyze secondary effects and apply stiffness methods in advanced scenarios.
CO3: Solve nonlinear structural problems using numerical approaches.
CO4: Apply FEM to 1D and 2D solid mechanics problems.
CO5: Employ energy methods for deformation and force analysis in solids.

Textbooks:

1. S.S. Bhavikatti – Finite Element Analysis, New Age International
2. R.D. Cook – Concepts and Applications of Finite Element Analysis, Wiley
3. Chandrupatla and Belegundu – Introduction to Finite Elements in Engineering, Pearson

Reference Books:

1. Timoshenko & Goodier – Theory of Elasticity, McGraw Hill
2. Bathe K.J. – Finite Element Procedures, Prentice Hall
3. G.R. Liu & S.S. Quek – The Finite Element Method: A Practical Course, Butterworth- Heinemann
4. Logan, D.L. – A First Course in the Finite Element Method, Cengage Learning