COURSECONTENT

FINITE ELEMENT ANALYSIS								
II Semester: SE								
Course Code	Category	Hours/ Week			Credits	Maximum Marks		
2522013	Core	L	T	P	C	CIA	SEE	Total
		3	0	0	3	40	60	100
contactClasses:45	Tutorial Classes: Nil	Practical Classes: Nil			TotalClasses:45			
Prerequisites: NIL.								

Course Overview:

This course introduces the fundamentals of the Finite Element Method (FEM) for analyzing engineering problems involving deformable bodies under various loading conditions. It covers formulation techniques such as virtual work, variational methods, and weighted residual approaches for 1-D, 2-D, and 3-D problems. The course emphasizes element formulations including truss, beam, plane stress/strain, and isoparametric elements. Advanced topics like numerical integration, convergence, and higher-order elements are also discussed. Practical exposure is provided through numerical examples and analysis using FEA software tools.

Course Objectives:

1. To understand the fundamentals of FEM, deformation behavior, and formulation of equilibrium, strain, and stress relations.
2. To learn variational and weighted residual methods and develop FEM formulations for 1D and 2D structural problems.
3. To understand isoparametric elements and develop FEM formulations using natural coordinates and numerical integration.
4. To formulate 3D finite elements, apply Galerkin's method, and develop stiffness and load matrices for 3D elements.
5. To perform FEM analysis and interpret results for 1D, 2D, and 3D models using numerical examples and FEA software.

Course Outcomes: After completion of the Course, student should be able to

1. Identify different types of materials, forces, and deformation problems and apply equilibrium equations in 2-D and 3-D continua.
2. Formulate finite element models for 1-D and 2-D problems using variational principles and approximation methods.
3. Construct shape functions and stiffness matrices for linear and quadratic isoperimetric quadrilateral elements using natural coordinates.
4. Explain finite element formulations for 3-D tetrahedral and hexahedral elements and apply Galerkin's method to structural problems.
5. Analyze 1-D, 2-D, and 3-D finite element models and interpret results using commercial FEA software.

UNIT–I

Introduction to FEM: Types of Problems – Types of Materials – Elastic / Inelastic situations – Types of forces: Body forces / Surface Traction / Point loads – Deformable bodies – Types of Deformations – Homogeneous / Non-homogeneous Problems – Equations of equilibrium for elastic 2-D / 3-D continua – Equilibrium equations for 2-D / 3-D boundary elements – Boundary conditions – Strain-displacement relation for 2-D / 3-D – Stress-strain relation for 2-D / 3-D – Plane stress / Plane strain problems.

Virtual Work Formulation: Application to problems of plane trusses with static indeterminacy not exceeding three.

UNIT–II

Variational Formulation: Approximate methods of Analysis – Weighted residual method – Rayleigh-Ritz Method – Strong form, weak form – Variational principle – Stationary Functional or Differential equation.

Finite element formulation for 1-D problems: Minimum Potential Energy Approach, weak form approach, introduction to natural coordinates – Finite element approximations in one dimension – Lagrangian approximation – Hermitian approximations – FE formulation for Axial bar, Euler-Bernoulli beam – Numerical Examples.

Finite element formulation for 2-D problems: FE Approximation in 2-Dimension, Pascal's triangle, Convergence criterion, Compatible and incompatible elements, FE Formulation for plane stress, plane strain and axi-symmetrical problems, Shape functions for 2-Dimensional CST element – 4 noded quadrilateral element – Higher order triangular and rectangular elements – Consistent nodal load vector – Numerical Examples.

UNIT–III

Iso-parametric elements:

Quadrilateral elements: FE Formulation for linear and quadratic isoparametric elements – Construction of shape functions using natural coordinates – Strain-displacement matrices – Load matrices for body force and surface traction – Expressions for stiffness matrix – Load matrices for 4-noded quadrilateral elements – Gauss Quadrature of numerical integration – Problems with rectangular elements, kinematic indeterminacy not exceeding three – Determination of shape functions for 2nd order quadrilateral elements and for elements with serendipity – Strain-displacement matrices – Load matrices for body force and surface traction.

UNIT–IV

Finite element formulation for 3-D elements:

FE Formulation for Tetrahedral and Hexahedral elements: Volume coordinates, Strain-displacement matrix, stiffness matrix, load matrices due to body force and surface traction, introduction to Hexahedron (brick) elements.

Galerkin's Method of Weighted Residuals: Application to problems of mathematics / structural engineering, number of trial functions not exceeding two.

Weak form of Trial Function: Application to problems of mathematics / structural engineering, number of elements limited to two – Strain-displacement relationship – Stress-strain relationship – Determination of stiffness matrix for 3-noded ring element and load matrices for body force and surface traction – Problems with kinematic indeterminacy not exceeding three for 3-noded ring elements only.

UNIT–V

Numerical examples: Simple 1-D model, 2-D model and a 3-D model – Analysis and post-processing of the results using commercially available FEA software and available codes.

TEXT BOOKS:

1. Reddy,J.N,(1993).―AnIntroductiontotheFiniteElementMethod‖,McGrawHill,NewYork.
2. Cook, R. D. (1981). ―Concepts and Application of Finite Element Analysis‖, JohnWiley and Sons.
3. Zienkiewicz,O.C.AndTaylor,R.L,(1989).―TheFiniteElementMethod‖,Vol.1,McGrawHill Company Limited, London.
4. Chandrupatla, T.R.AndBelegundu,A.D,(2001).―IntroductiontoFiniteElementsin Engineering‖, Prentice Hall of India, New Delhi.
5. Seshu.P,(2003).―FiniteElementAnalysis‖,PrenticeHallofIndiaPrivateLimited,NewDelhi.
6. DavidV.Hutton,(2005).―FundamentalsofFiniteElementAnalysis‖,TataMcGraw-Hill Publishing Company Limited, New Delhi.
7. Bathe,K.J,(2006).―FiniteElementProcedures‖,PrenticeHallofIndia,NewDelhi

ELECTRONIC RESOURCES:

https://nptel.ac.in/courses/112106135

MATERIALS ONLINE:

1. Course template
2. Tutorial question bank
3. Definitions and terminology
4. Assignments
5. Model question paper–I
6. Model question paper–II
7. Lecture notes
8. E-Learning Readiness Videos(ELRV)