Course Plan (Autumn-2025)

School: Engineering.

Department: Mechanical Engineering.

Course Code: ME428.

Course Name: Finite Element Methods in Engineering.

Course type : Elective

Credit Structure: L-T-P-Cr-CH:: 3-0-0-3-3

Instructor: Dr. Sushen Kirtania, Associate Professor, Department of Mechanical Engineering, Phone: +91 3712 27 5857, Email: sushen@tezu.ernet.in.

1. Abstract: The finite element method (FEM) is a numerical technique that is used to find approximate solutions of partial differential equations (PDEs). Since the behaviours of almost all physical systems can be represented with the help of PDEs, therefore FEM can be used to analyse many physical problems. With the help of this method, differential equations can be reduced to algebraic equations by using suitable approximations of the variables over the elements. The FEM is practically useful for engineering problems with those problems being too complicated to be solved by the classical analytical method. Complex geometry and a variety of material properties can also be handled using FEM. Due to these advantages, FEM has emerged as a versatile and powerful tool in computational engineering.

2. Objectives: The main objectives of this course are to

i. introduce the basic principles, need of FEM, different steps, and approaches to solve a problem using FEM.
ii. introduce the mathematical concepts of the FEM for obtaining an approximate solution of PDEs.
iii. find the solution in many points as many as we want of an object by discretizing the object.
iv. reduce the hectic task for the repetition of fabrication and experiments of an engineering component.
v. develop proficiency in solving realistic engineering problems using commercial FE software packages (ANSYS).
vi. encourage students for higher education by acquiring in-depth knowledge of FEM.

3. Prerequisites of the course: None.

4. Course outline: Introduction to FEM, FE analysis of one dimensional (1D) problems, Interpolation functions and element characteristics, FE analysis of 2D problems, Introduction to the calculus of variation, Approximate methods of analysis, Numerical integration, Assignment on modeling, analysis and design of structural component using commercial software package (ANSYS).

5(a). Time plan:

Sl.	Topics	Contents	L
1.	Introduction to FE method	Basic concept of FEM, Historical background, Need of FEM, Advantages and limitations of FEM, Real-life application of FEM.	4
2.	Analysis of 1D problems	Different approaches in FEM: General steps of FE method; Direct formulation of an axial rod problem - Discretization procedures, Derivation of elemental equations and their assembly, Application of boundary conditions, Solution and post processing; Solving of problems using the direct approach. Analysis of Truss: Derivation of the element stiffness matrix, Global stiffness matrix, Solution of truss problems.	7
3.	Interpolation functions and Element	Interpolation function (IF) or shape function: Polynomial, Line elements, Lagrangian form of IF, IF of bar elements, Length coordinate for higher-order element, IF of beam elements.	7

	characteristics	Element characteristics: Element stiffness matrix of bar and beam elements, solution of beam problems.	
4.	Analysis of 2D problems	Triangular elements: Area coordinates, Determination of shape function of higher order triangular elements. Rectangular elements: Derivation of shape function of rectangular element, Serendipity approach, Higher order rectangular elements, Isoparametric formulation, Coordinate transformation, Solution of 2D problems.	8
5.	Introduction to the calculus of variation	Calculus of variation, Functional, Exetremization of functional, Properties of variational operation, Variational form from a differential equation and vice-versa, Solution of problems.	3
6.	Approximate methods of analysis	Different types of approximate methods, Ritz method, Method of weighted residual, Galerkin's method, solving problems using Ritz and Galerkin method.	7
7.	Numerical integration	Need of numerical integration in FEM, Gauss Quadrature in 1D and 2D, solving problems using Gauss Quadrature rule.	4
8.	Assignments	Modelling and analysis of structural components using the commercial FE software package (ANSYS).	2

Total number of classes: 42

5(b). Evaluation plan:

Test No.	Marks	Duration
Sessional Test - I	10	30 minutes
Mid-Semester Examination	30	90 minutes
Sessional Test – II (Assignments)	10	---
End-Semester Examination	50	2 hours

6. Pedagogy: Lecture and discussion, Class tests, Assignments, FEA software learning.

7. Course outcomes: Towards the end of the course the students could be able to

CO1 understand the concept of FEM, learn the behaviours and uses of different types of elements by developing stiffness matrix.

CO2 solve 1D and 2D problems using the concept of shape function by developing element stiffness matrices.

CO3 solve differential equations using approximate methods and complicated integration problems by using numerical integration technique.

CO4 solve complex geometric problems using the commercial FE software package, after that write and present their assignment as a technical report.

Text Books:

1. Desai YM, Eldho TI, and Shah AH. *Finite Element Method with Applications in Engineering*, Pearson, 2019
2. Dixit US. *Finite Element Methods for Engineers*, Cengage Learning, 2018.

Reference Books:

1. Seshu P. *Textbook of Finite Element Analysis*, Prentice-Hall India, 2014.
2. Chandrupatla TR and Belegundu AD. *Introduction to Finite Elements in Engineering*, Pearson, 4t ed., 2019.
3. Huebner KH, Dewhirst, DL, Smith DE and Byrom TG. *The Finite Element Method for Engineers*, Wiley-Interscience, 4th ed., 2001.
4. Hutton DC. *Fundamentals of Finite Element Analysis*, Tata McGraw-Hill, 2005.
5. Reddy JN. *An introduction to the Finite Element Method*, Tata McGraw-Hill, 2006.