Course Plan (Spring-2025)

School : Engineering.

Department : Mechanical Engineering.

Course Code : ME502.

Course Name : Finite Element Methods.

Course type : Core

Credit Structure: L-T-P-Cr-CH: 3-1-0-4-4

Instructor: Dr. Sushen Kirtania, Assoc. 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 used for finding approximate solutions of partial differential equations. Since the behavior of almost all physical systems can be represented with the help of partial differential equations, therefore FEM can be used to analyse several 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 problem with those problems is too complicated to be solved by the classical analytical method. Complicated geometries and 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. Course objectives: The main objectives of this course are –

(i) To introduce the basic principles and need of FEM.
(ii) To understand the different steps and approaches to solve a problem using FEM.
(iii) To introduce the mathematical concepts of the FEM for obtaining an approximate solution of partial differential equations.
(iv) To find the solution in many points as many as we want of an object by discretizing the object.
(v) To reduce the hectic task for repetition of fabrication and experiments of an engineering component.
(vi) To develop proficiency in solving realistic engineering problem using commercial finite element (FE) software package (ANSYS).
(vii) To train the students for writing and presenting a technical report by giving assignments and mini projects.
(viii) To encourage student for higher education by acquiring in-dept knowledge of FEM.

3. Prerequisites of the course: None.

4. Course outline: Introduction to FEM, Finite element analysis (FEA) of one dimensional (1D) problem, Interpolation functions and Element characteristics, FEA of two dimensional (2D) problems, Introduction to three dimensional (3D) problems, Variational methods, Numerical considerations, Further applications of FEM, Miscellaneous topics, Hands-on practice session for modelling and analysing of structural components using the commercial FE software package ANSYS.

5(a). Time plan:

Sl	Topics	Contents	L	T
1.	FEM: An introduction	Basic concept of FEM, Historical background, Need of FEA, Advantages and limitations of FEM, Real life applications of FEM.	3	-
2.	One-	Different approaches in FEM: Direct formulation of bar element,		

	dimensional FE analysis	Discretization procedures, Derivation of elemental equations and their assembly, Application of boundary conditions, Solution and post processing, Direct formulation and solution of bar, spring and truss element problems, 1D heat transfer problems.	8	3
3.	Interpolation functions and Element characteristics	Interpolation function (IF) or shape function: Polynomials, Lagrangian form of IF, IF of bar elements, IF of higher order element in 1D, IF of beam elements. Element characteristics: Element stiffness matrix of bar and beam elements, solution of beam problems.	5	2
4.	Two-dimensional FE analysis	Triangular elements: Area coordinate, Determination of shape functions of higher order triangular elements. Rectangular elements: Derivation of shape function of rectangular elements, Serendipity approach, Higher order rectangular elements, Isoparametric formulation, Coordinate transformation, Applications in solid mechanics, fluid mechanics and heat transfer.	10	3
5.	Variational methods	Calculus of variation: Functional, Variational operator, Variational form from differential equation and vice-versa. Approximate method of analysis: Ritz method, Method of Weighted residual and Galerkin method.	7	2
6.	Numerical considerations	Numerical integration (NI): Need of NI in FEM, Gauss quadrature in 2D, Error analysis.	3	1
7.	Applications of FEM	Plane stress and plane strain problems, Bending of plates, Eigen values and time dependent problems.	2	-
8.	Miscellaneous topics	FE solution versus exact solution, Essential and natural boundary conditions, Mesh refinements, Finite difference method, Patch test.	2	-
9.	Assignment and mini-project	Modelling and analysis of structural components mainly using the commercial FE software package (ANSYS) or using any commercial software package.	2	3

Total number of classes: (42+14) = 56

5(b). Evaluation plan:

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

6. Pedagogy: Lecture and discussion, Class tests, Assignments, and mini project.

7. Course outcomes: Towards the end of the course the student would be able to

CO1: Understand the concept of FEM, learn the behaviour and uses of different types of elements by developing stiffness matrix.
CO2: Solve one-dimensional problems using the concept of shape function.
CO3: Solve two-dimensional problems using the concept of shape function by developing triangular and quadrilateral element stiffness matrices.
CO4: Solve differential equations using approximate methods and complicated integration problem by using numerical integration technique.
CO5: Solve the complex geometric problems using the commercial FE software package after that write and present their assignments 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, 4^{th} ed., 2019.
3. Huebner KH, Dewhirst, DL, Smith DE and Byrom TG. *The Finite Element Method for Engineers*, Wiley-Interscience, 4^{th} ed., 2001.
4. Hutton DV. *Fundamentals of Finite Element Analysis*, Tata McGraw-Hill, 2005.
5. Reddy JN. *An introduction to the Finite Element Method*, Tata McGraw-Hill, 2006.