FINITE ELEMENT ANALYSIS

I Semester

Course Code: 19ME2102

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Course Outcomes: At the end of the course, the student will be able to

CO1: Apply Rayleigh-Ritz, Galerkin methods to solve engineering problems and analyze linear 1D problems like bars and trusses.

CO2: Analyze 2D structural problems using CST element and axi-symmetric problems with triangular elements.

CO3: Explain shape functions for 4 and 8 noded quadrilaterals, 6 noded triangle elements and apply numerical integration to solve; 1D and 2D; stiffness integration.

CO4: Solve linear 2D structural beams and frames problems; 1D heat conduction and convection heat transfer problems.

CO5: Calculate the Eigenvalues and Eigenvectors for stepped bar and beam, explain geometric and material nonlinearity.

UNIT-I **(10-Lectures)**

Introduction, comparison of FEM with other methods, Galerkin Methods. Rayleigh- Ritz method, shape functions and characteristics, properties of stiffness matrix, treatment of boundary conditions, Convergence: requirements for convergence, h refinement and p- refinement, basic equations of elasticity, strain displacement relations.

1-D structural problems – axial bar element – stiffness matrix and load vector, Plane trusses, element stiffness matrix, assembly of global stiffness matrix and load vector, stress calculations.

Learning outcomes:

1. Apply Rayleigh-Ritz and Galerkin methods to solve engineering problems. (L3)
2. Analyze linear 1D problems like bars. (L4)
3. Solve linear 1D problems like trusses. (L3)

UNIT-II **(10-Lectures)**

Two-dimensional problems using CST: FE modelling, isoparametric representation, PE approach, element stiffness, force terms, stress calculations .

Axisymmetric formulation, FE Modelling using triangular elements, body force terms, surface traction, stress calculations, cylinder subjected to internal pressure, infinite cylinder.

Learning outcomes:

1. Analyze 2D structural problems using CST element. (L4)
2. Analyze 2D axi-symmetric problems with triangular elements. (L4)
3. Calculate surface traction using 2D elements. (L3)

UNIT-III **(10-Lectures)**

Isoparametric formulation: 4-noded quadrilateral and its shape functions, element stiffness matrix, element force vectors, nine - noded quadrilateral, eight-noded quadrilateral, six-node triangle, sub parametric, super parametric elements, serendipity elements.

Numerical Integration- 1D and 2D integrations, stiffness integration, stress calculations.

Learning outcomes:

1. Explain shape functions for 4 and 8 noded quadrilaterals, 6 node triangle elements. (L2)
2. Apply numerical integration to solve; 1D and 2D; stiffness integrations. (L3)

3. Explain sub parametric, super parametric elements, serendipity elements. (L2)

UNIT-IV **(10-Lectures)**

Beams and frames: finite element formulation, load vector, boundary conditions, shear force and bending moment, and plane frames .
Scalar field problems: steady state heat transfer-one-dimensional heat conduction problems, one-dimensional heat transfer in thin fins.
Learning outcomes:

1. Solve linear 2D structural beam problems. (L3)
2. Solve linear 2D structural frame problems. (L3)
3. Solve linear 1D heat conduction and convection heat transfer problems. (L3)

UNIT-V **(10-Lectures)**

Dynamic analysis and nonlinear FEA: formulation-solid body with distributed mass, element mass matrices, evaluation of Eigenvalues and Eigenvectors for a stepped bar and a beam, Introduction to nonlinear problems, geometric nonlinearity, material nonlinearity nonlinear dynamic problems, analytical problems.

Learning outcomes:

1. Evaluate the Eigenvalues and Eigenvectors of stepped bar. (L5)
2. Evaluate the Eigenvalues and Eigenvectors of beam. (L5)
3. Explain geometric and material nonlinearity. (L2)

TEXT BOOK:

1. Tirupathi R. Chandrupatla and Ashok D. Belegundu, *Introduction to Finite Elements in Engineering*, 4th Edition, Pearson Education,2011.

REFERENCE BOOKS:

1. S.S. Rao, *The Finite Element Method in Engineering*, 5th Edition, Butterworth and Heinnemann, 2010.
2. O. P. Gupta, *Finite and Boundary Element Methods in Engineering*, 2nd Edition, Taylor and Francis, 1999.
3. J. N. Reddy, *An Introduction to Finite Element Methods*, 2nd Edition, McGraw Hill, 2009.