K.S. SCHOOL OF ENGINEERING AND MANAGEMENT, BENGALURU - 560109

DEPARTMENT OF MECHANICAL ENGINEERING

SESSION: 2022-2023 (EVEN SEMESTER)

CO-PO MAPPING

Course: Finite Element Method			
Type: Core		**Course Code:18ME61**	
No of Hours per week			
Theory (Lecture Class)	Theory (Lecture Class)	Theory (Lecture Class)	Total teaching hours
4	4	4	50
Marks			
Internal Assessment	Internal Assessment	Internal Assessment	Credits
40	40	40	4

Aim/Objective of the Course:

To have a knowledge of different coordinate systems

1. To have a knowledge of shape functions
2. To have a working knowledge of solving problems by finite element method
3. To get an idea of finding frequency and mode shapes of the elements

Course Learning Outcomes

After completing the course, the students will be able to

CO1	Explain the basic concepts of Theory of Elasticity, basic principles of Finite Element Method and solve problems by using Potential energy principles, RR and Galerkins method	**Applying (K3)**
CO2	Derive the shape functions for different types of elements and Solve the Problems on Trusses and bars	**Applying (K3)**
CO3	Solve the problems on beams and derive the equations of deflection in beams	**Applying (K3)**
CO4	Derive the stiffness matrix and solve the thermal problems using FEM	**Applying (K3)**
CO5	Derive the displacement, stress and strain relation for axisymmetric problems and solve the same numeric	**Applying (K3)**

Syllabus Content

MODULE: 1 **Introduction to Finite Element Method:** General description of the finite element method. Engineering applications of finite element method. Boundary conditions: homogeneous and nonhomogeneous for structural, heat transfer and fluid flow problems. Potential energy method, Rayleigh Ritz method, Galerkin's method, Displacement method of finite element formulation. Convergence criteria, Discretization process, Types of elements: 1D, 2D and 3D, Node numbering, Location of nodes. Strain displacement relations, Stress strain relations, Plain stress and Plain strain conditions, temperature effects.	CO1 08 hrs PO1-3 PO2-3 PO3-3 PO4-2 PO5-2

Interpolation models: Simplex, complex and multiplex elements, Linear interpolation polynomials in terms of global coordinates 1D, 2D, 3D Simplex Elements LO: After the completion of the chapter the student will be able to 1. Summarize the fundamentals of Theory of Elasticity 2. Identify a problem as plane stress or plane strain based on loading and geometry of the structure 3. Describe the basic principles of Finite Element Method with its applications and limitations 4. Identify the different types of elements used in Finite Element Method	PO6-1 PO12-1

MODULE: 2 **One-Dimensional Elements-Analysis of Bars Trusses:** Linear interpolation polynomials in terms of local coordinate's for 1D, 2D elements. Higher order interpolation functions for 1D quadratic and cubic elements in natural coordinates, Constant strain triangle, Four-Nodded Tetrahedral Element (TET 4), Eight-Nodded Hexahedral Element (HEXA 8), 2D isoperimetric element, Lagrange interpolation functions, Numerical integration: Gaussian quadrature one point, two point formulae, 2D integrals. Fore terms: Body force, traction force and point loads **Numerical Problems:** Solution for displacement, stress and strain in 1D straight bars, stepped bars and tapered bars using elimination approach and penalty approach, Analysis of trusses LO: After the completion of the chapter the student will be able to:- 1. Derive Euler-Lagrange equation and apply it to bars, beam (cantilever/simply supported and fixed) with different loading and end conditions 2. Describe the Principle of virtual work and principle of minimum potential energy 3. Summarize Rayleigh Ritz method and Galerkin's method and determine the displacement, strain and stress in bars and beams using those methods	CO2 08 hrs PO1-3 PO2-3 PO3-2 PO4-2 PO5-2 PO6-1 PO12-1
MODULE: 3 **Beams and Shafts**: Boundary conditions, Load vector, Hermite shape functions, Beam stiffness matrix based on Euler-Bernoulli beam theory, Examples on cantilever beams, propped cantilever beams, Numerical problems on simply supported, fixed straight and stepped beams using direct stiffness method with concentrated and uniformly distributed load. **Torsion of Shafts:** Finite element formulation of shafts, determination of stress and twists in circular shafts. LO: Student will be able to 1. Explain the interpolation polynomials corresponding to different element types used in FEM 2. Define simplex, complex and multiplex elements 3. Explain the use of 2D PASCAL's triangle in determining the polynomial function for an element in FEM 4. Explain with an illustration the importance of Jacobian transformation	CO3 08 hrs PO1-3 PO2-3 PO3-3 PO4-2 PO5-2 PO6-1 PO12-1

matrix.	
MODULE: 4 **Heat Transfer:** Basic equations of heat transfer: Energy balance equation, Rate equation: conduction, convection, radiation, energy generated in solid, energy stored in solid, 1D finite element formulation using vibrational method, Problems with temperature gradient and heat fluxes, heat transfer in composite sections, straight fins. LO: Student will be able to 1. Derive the shape function, element stiffness matrix and load vector matrix of a bar element used in FEM 1. Analyse the structural problems involving bars for maximum stresses by discretizing it with 1D bar elements	CO4 08 hrs PO1-3 PO2-3 PO3-3 PO4-2 PO5-2 PO6-1 PO12-1
MODULE: 5 **Axi-symmetric Solid Elements:** Derivation of stiffness matrix of axisymmetric bodies with triangular elements, Numerical solution of axisymmetric triangular element(s) subjected to point loads. **Dynamic Considerations:** Formulation for point mass, Consistent element mass matrix of one-dimensional bar element, truss element, Lumped mass matrix of bar element, truss element. LO: Student will be able to 1. Apply Langrange's interpolation function to determine the shape function for higher order 1D, 2D elements. 2. Distinguish between Iso, sub and super parametric elements. Evaluate the given integral using one point and two-point Gauss-quadrature	CO5 08 hrs PO1-3 PO2-3 PO3-3 PO4-2 PO5-2 PO6-1 PO12-1

Text Books:

1. **Logan, D. L.,** A first course in the finite element method,6th Edition, Cengage Learning, 2016.
2. **Rao, S. S.,** Finite element method in engineering, 5th Edition, Pergaman Int. Library of Science, 2010.
3. R.Chandrupatla, "Introduction to Finite Elements in Engineering", 4^{th} Edition, Prentice Hall, 2013.

Reference Books (specify minimum two foreign authors textbooks)

1. J.N.Reddy, "Finite Element Method"- McGraw -Hill International Edition. Bathe K. J. Finite Elements Procedures, PHI.
2. Cook R. D., et al. "Concepts and Application of Finite Elements Analysis"- 4th Edition, Wiley & Sons, 2003
3. Olek C Zienkiewicz, Robert L Taylor, J.Z. Zhu, "The Finite Element Method: Its Basis and Fundamentals", 6^{th} Edition, Butterworth Heinemann 2005.

Useful Websites

- http://audilab.bmed.mcgill.ca/AudiLab/teach/fem/fem.html
- http://nptel.ac.in/courses/112104115/
- http://freevideolectures.com/Course/2358/Introduction-to-Finite-Element- Method

Useful Journals

- Finite Elements in Analysis and Design, An International Journal for Innovations in Computational Methodology and Application, Elsevier.
- International Journal of Computational Methods, World Scientific.

Teaching and Learning Methods

1. Lecture class: 40 hours
2. Practical classes: 3 hours

Assessment

Type of test/examination: Written examination

Continuous Internal Evaluation(CIE) : 40 marks (30 marks -Average of three tests + 10 marks Assignments)

Semester End Exam(SEE) : 100 marks (students have to answer all main questions) which will be reduced to 60 Marks.

Test duration: 1 :30 hours

Examination duration: 3 hours

CO to PO Mapping

PO1: Science and engineering Knowledge	**PO7:** Environment and Society
PO2: Problem Analysis	**PO8:** Ethics
PO3: Design & Development	**PO9:** Individual & Teamwork
PO4: Investigations of Complex Problems	**PO10:** Communication
PO5: Modern Tool Usage	**PO11:** Project Mngmt & Finance
PO6: Engineer & Society	**PO12:** Life long Learning

PSO1: Ability to apply concept of mechanical engineering to design a system, a component or a process/system to address a real world challenges

PSO2: Ability to develop effective communication, team work, entrepreneurial and computational skills

CO	PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO11	PO12	PS O1	PS O2
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CO1	K3	3	3	3	2	-	1	-	-	-	-	-	1	3	1
CO2	K3	3	3	2	2	-	1	-	-	-	-	-	1	3	1
CO3	K3	3	3	3	2	1	1	-	-	-	-	-	1	3	1
CO4	K3	3	3	3	2	1	1	-	-	-	-	-	1	3	1
CO5	K3	3	3	3	2	1	1		-	-	-	-	1	3	1

Course In charge | **Head of the Department** | **Principal**