Total No. of Questions: 20 **Enrollment No :** ____________________

Faculty of Engineering

End Semester Examination May 2025

ME3EL05 Finite Element Method

Programme	:	B.Tech.	**Branch/Specialisation**	:	ME
Duration	:	3 hours	**Maximum Marks**	:	60

Note: *All questions are compulsory. Internal choices, if any, are indicated. Assume suitable data if necessary. Notations and symbols have their usual meaning.*

Section 1 (Answer all question(s)) **Marks CO BL**

Q1. Which of the following is not a mathematical model for structural problems? **1 1 1**
- ○ Differential formulation
- ○ Energy approach
- ○ Variational formulation
- ● Linear regression

Q2. The principle of virtual work is associated with- **1 1 1**
- ○ Differential formulation
- ○ Integral formulation
- ● Variational formulation
- ○ Residual methods

Q3. The concept of discretization in FEM refers to- **1 2 1**
- ● Dividing the domain into finite elements
- ○ Solving differential equations analytically
- ○ Applying boundary conditions
- ○ Minimizing potential energy

Q4. Which of the following is not a step in the FEM process? **1 2 1**
- ○ Discretization
- ○ Interpolation
- ○ Assembly
- ● Linearization

Q5. The stiffness matrix for a bar element is derived using- **1 3 1**
- ● Hooke's law
- ○ Newton's second law
- ○ Fourier's law
- ○ Bernoulli's principle

Q6. Which method is used to incorporate boundary conditions in FEM? **1 3 1**
- ● Elimination method
- ○ Substitution method
- ○ Iteration method
- ○ Relaxation method

Q7. The Jacobian matrix is used in FEM to- **1 4 1**
- ● Transform local coordinates to global coordinates
- ○ Apply boundary conditions
- ○ Calculate stiffness matrices
- ○ Minimize potential energy

Q8. Plane stress and plane strain problems differ in- **1 4 1**
- ● The assumption of stress/strain in the third dimension
- ○ The type of elements used
- ○ The boundary conditions applied
- ○ The material properties

Q9. The finite element solution for 1D heat conduction includes- **1 5 1**
- ● Convective boundary conditions
- ○ Dirichlet boundary conditions
- ○ Neumann boundary conditions
- ○ No boundary conditions

Q10. Modal analysis in dynamic problems involves- **1 5 1**

- (selected) Determining natural frequencies and mode shapes
- Calculating stress distributions
- Applying thermal loads
- Solving heat conduction

Section 2 (Answer all question(s))

Marks CO BL

Q11. What is the primary purpose of the Finite Element Method (FEM)? **2 1 2**

Rubric	Marks
Correctly identifies FEM as a method for solving continuum problems.	2

Q12. (a) Explain the concept of mathematical modeling in FEM and discuss the differential and variational formulations. **8 3 3**

Rubric	Marks
Definition, importance, and role of mathematical models in FEM.	3
Explanation of governing differential equations, boundary conditions, and strong form.	3
Derivation of weak form, energy principles, and connection to FEM.	2

(OR)

(b) Discuss the historical development of FEM and its applicability to mechanical engineering problems.

Rubric	Marks
Key milestones in FEM evolution, contributions from Courant, Turner, Clough, and Zienkiewicz.	3
Development of shape functions, stiffness matrix formulation, and numerical techniques.	3
Applications in structural analysis, heat transfer, fluid mechanics, and material modeling.	2

Section 3 (Answer all question(s))

Marks CO BL

Q13. What are shape functions, and what is their role in FEM? **2 1 1**

Rubric	Marks
Accurately defines shape functions and their role in approximating solutions.	2

Q14. (a) Explain the generalized finite element formulation based on the weighted residual method. **8** **2** **3**

Rubric	Marks
Explanation of differential equations, approximation, and residual concept.	3
Explanation of weighting functions and different WRM approaches (Galerkin, Petrov-Galerkin, etc.).	3
Derivation of weak form, shape functions, matrix formulation, and system of equations.	2

(OR)

(b) Discuss the concept of discretization and its importance in FEM.

Rubric	Marks
Definition, explanation of converting a continuum into finite elements, and types of elements.	3
Explanation of element connectivity, nodal approximation, and interpolation functions.	3
Discussion on mesh refinement, element types, and numerical accuracy.	2

Section 4 (Answer all question(s)) **Marks CO BL**

Q15. What are the advantages of higher-order elements in FEM? **2** **3** **2**

Rubric	Marks
Accurately lists advantages like better accuracy and convergence.	2

Q16. (a) Derive the finite element characteristics for beam elements and discuss their applications. **8** **3** **3**

Rubric	Marks
Explanation of beam theories (Euler-Bernoulli & Timoshenko), governing differential equations.	3
Derivation of shape functions, weak form, element stiffness matrix, and load vector.	3
Application of boundary conditions, assembly into the global system, and solution methods.	2

(OR)

(b) Derive the stiffness matrix for a bar element and explain its significance.

Rubric	Marks
Definition of bar element, assumptions, and governing equation (1D elasticity).	3
Step-by-step derivation using shape functions and weak form (Galerkin or variational approach).	3
Explanation of its role in FEM, system of algebraic equations, and global assembly.	2

Section 5 (Answer all question(s)) **Marks CO BL**

Q17. What are the advantages of using triangular and quadrilateral elements in FEM? **2 1 3**

Rubric	Marks
Correctly lists advantages like flexibility and accuracy.	2

Q18. (a) Explain the concept of interpolation in two dimensions and its applications in FEM. **8 3 1**

Rubric	Marks
Explanation of interpolation in 2D, definition of shape functions, and mathematical representation.	3
Description of linear, quadratic, and higher-order interpolation techniques.	3
Use of interpolation in element formulation, natural coordinates, and isoparametric elements.	2

(OR)

(b) Discuss the formulation of plate bending elements using linear and higher-order bending theories.

Rubric	Marks
Explanation of Kirchhoff (classical) and Mindlin-Reissner (higher-order) plate theories.	3
Weak form derivation, element selection, shape functions, and matrix formulation.	3
Discussion of boundary conditions, solution techniques, and computational aspects.	2

Section 6 (Answer all question(s))

Marks CO BL

Q19. What is the finite element solution for 1D heat conduction? **2 1 1**

Rubric	Marks
Correctly explains the solution process and its significance.	2

Q20. (a) Discuss the finite element applications in potential flows using the potential function and stream function. **8** **4** **4**

Rubric	Marks
Explanation of velocity potential, stream function, and Laplace equation.	3
Application of FEM, weak form, and matrix formulation.	3
Relevant applications in aerodynamics, groundwater flow, and electrostatics.	2

(OR)

(b) Derive the dynamic equations of motion using the Lagrangian method in FEM.

Rubric	Marks
Correct derivation of kinetic and potential energy expressions for the system.	3
Proper application of Lagrange's equation to derive the equations of motion.	3
Correct formulation of the final dynamic FEM equations with interpretation.	2

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