Register No : ____________________

THE KAVERY ENGINEERING COLLEGE

(An Autonomous Institution)

UG/PG DEGREE END SEMESTER THEORY EXAMINATIONS, APRIL-MAY 2026

Second Semester

M.E Product Design and Development

PPDT2421 - FINITE ELEMENT METHODS IN MECHANICAL DESIGN

Regulations - 2024

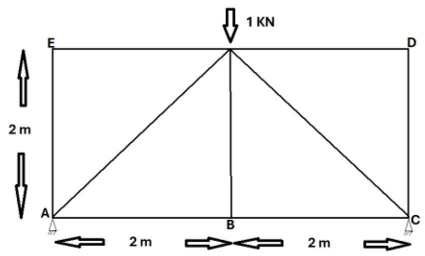
Duration : 3 Hrs ***Maximum : 100 Marks***

PART – A(ANSWER ALL QUESTIONS) (Marks 10*2=20)

Q.No	Questions	BTL	CO	Marks
1.	State the principle of minimum potential energy.	L1	1	2
2.	What is a shape function? List its properties.	L1	1	2
3.	Differentiate between a scalar and a vector variable problem. Give an example of each.	L2	2	2
4.	What is the significance of the [B] matrix in the finite element method?	L2	2	2
5.	What is an isoparametric element?	L1	3	2
6.	Why is numerical integration necessary in isoparametric finite element formulation?	L2	3	2
7.	Define an eigenvalue problem in the context of structural mechanics.	L1	4	2
8.	List any two numerical methods used to solve eigenvalue problems in FEA.	L1	4	2
9.	What are the main sources of non-linearity in structural analysis?	L2	5	2
10.	Differentiate between material non-linearity and geometric non-linearity.	L2	5	2

PART – B (ANSWER ALL QUESTIONS) (Marks 5*16 = 80)

Q.No			Questions	BLT	CO	Marks
11.	a	i	For a two-noded one-dimensional linear bar element, derive the shape functions and the strain-displacement matrix [B].	L3	1	8
		ii	A bar of length 200 mm is subjected to an axial load of 50 kN. The bar has a stepped cross-section: 50 mm² for the first 100 mm and 30 mm² for the next 100 mm. If E = 2×10^5 N/mm², determine the total elongation of the bar by modeling it as two finite elements.	L3	1	8
			Or			
	b	i	Derive the stiffness matrix for a two-noded one-dimensional truss element (or bar element inclined at an angle θ) in global coordinates.	L3	1	8
		ii	For the pin-jointed truss shown in Figure below (or described: two elements, nodes (0,0), (1000,0), (0,1000) with equal area A and modulus E), determine the displacements at node 3. Use A = 250 mm², E = 200 GPa.	L3	1	8



12.	a	i	Derive the element stiffness matrix and nodal load vector for a two-dimensional constant strain triangular (CST) element.	L4	2	8
		ii	Derive the element stiffness matrix for a linear rectangular element.	L4	2	8
			Or			
	b	i	Explain in detail the procedure to solve a 2D heat transfer (scalar variable) problem using the finite element method.	L4	2	8
		ii	A thin plate (plane stress) is subjected to a traction load on one edge. Describe how the consistent load vector is formulated for this edge for a CST element.	L4	2	8
13.	a	i	Explain the concept of isoparametric, subparametric, and superparametric elements with suitable examples.	L3	3	6
		ii	For a 4-noded quadrilateral isoparametric element, derive the Jacobian matrix [J] that relates the natural coordinate derivatives to the global coordinate derivatives.	L3	3	10
			Or			
	b	i	Describe the Gauss-Legendre numerical integration technique. Why is it preferred over other numerical methods in FEA?	L3	3	6
		ii	Evaluate the integral $I = \int_{-1}^{1}(3\,\xi^4 + 2\xi^2 - 5)\,d\xi$ using 2-point and 3-point Gauss quadrature. Compare the results with the exact integration.	L3	3	10
14.	a		Formulate the finite element equations to determine the natural frequencies of longitudinal vibration of a stepped bar.	L3	4	16
			Or			
	b		A fixed-free rod has a length L, modulus of elasticity E, and mass density ρ. Using a single bar element, determine the fundamental natural frequency of axial vibration.	L3	4	16
15.	a	i	What are the different solution techniques for solving non-linear equations in FEA? Explain the Newton-Raphson method in detail.	L4	5	8
		ii	A non-linear spring is characterized by the force-displacement relationship $F(u) = 50u + 20u^2$. Determine the displacement u for an applied force $F = 150N$ using one iteration of the Newton-Raphson method. Start with an initial guess of $u_0 = 1.0$.	L4	5	8
			Or			
	b		Derive the finite element formulation for a one-dimensional non-linear problem arising from material non-linearity (e.g., a bar with a non-linear stress-strain relationship).	L4	5	16
