PSN COLLEGE OF ENGINEERING AND TECHNOLOGY

(An Autonomous Institution, Affiliated to Anna University, Chennai)
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Melathediyoor, Palayamkottai, Tirunelveli – 627 152

DEPARTMENT OF MECHANICAL ENGINEERING

Question Bank / End Semester Examinations, October / November 2023

Year & Sem	IV Yr & VII Sem	Branch	B.E. Mechanical Engineering
Course Code	510023	Course Name	Finite Element Analysis
Regulation	2018	Academic Year	2023 – 24 (Odd)

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

CO1: Apply the numerical methods to formulate the simple finite element problems.

CO2: Apply one dimensional finite element method to solve bar, beam and truss type Problems

CO3: Apply finite element method for plane stress, plane strain and axis symmetric conditions.

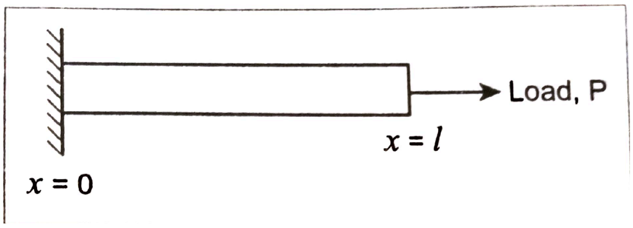
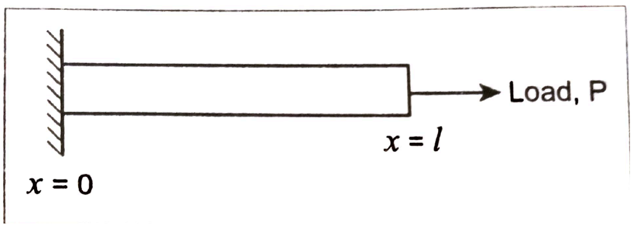
CO4: Identify temperature distribution of one- and two-dimensional heat transfer problems using one- and two-dimensional finite elements.

CO5: Apply the numerical methods to formulate the higher order and isoperimetric problems.

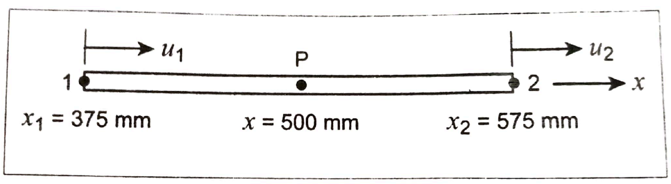
BL – *Bloom's Level (1- Remembering, 2- Understanding, 3 – Applying, 4 – Analysing, 5 –Evaluating, 6 - Creating)*; **CO** – *Course Outcome*;

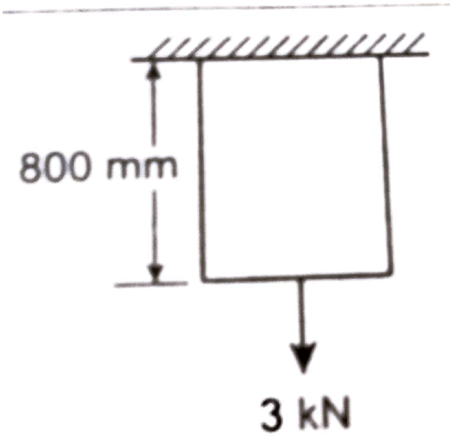
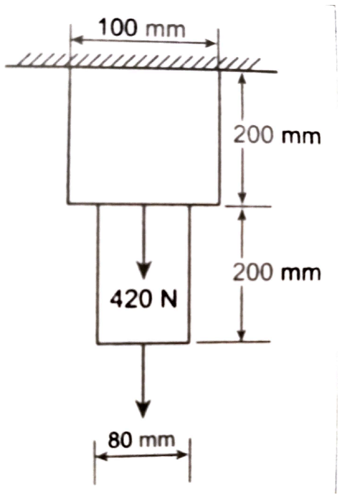
Unit I: INTRODUCTION TO FINITE ELEMENT ANALYSIS				
Q. No.	**Part – A (2 Marks)**	**Marks**	**CO**	**BL**
1	Classify boundary conditions.	2	CO1	1
2	Name the weighted Residual methods.	2	CO1	1
3	State the method of engineering analysis.	2	CO1	1
4	What are the limitations of using a finite difference method?	2	CO1	1
5	What is Galerkin method of approximation?	2	CO1	1
6	Mention the basic steps of Reyleigh – Ritz method.	2	CO1	1
7	List the different types of nodes.	2	CO1	1

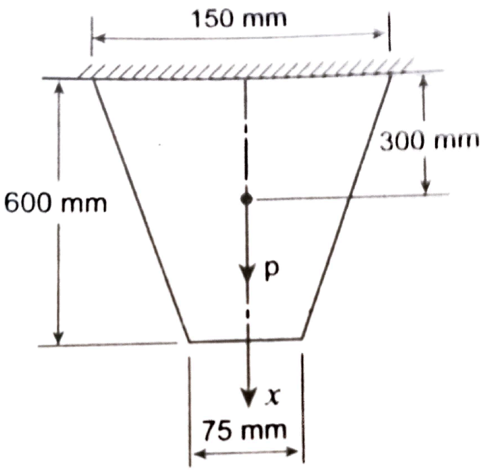
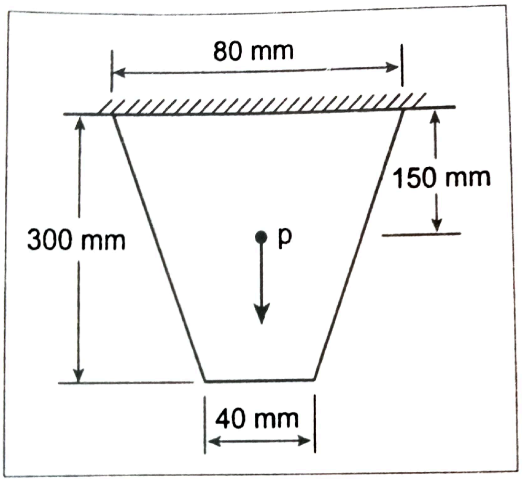
8	What is the basis of finite element method?	**2**	**CO1**	**1**
9	Name the variational methods.	**2**	**CO1**	**1**
10	What is interpolation function?	**2**	**CO1**	**1**
11	Why are polynomial type of interpolation function preferred over trigonometric functions?	**2**	**CO1**	**1**
12	Name the FEA software's.	**2**	**CO1**	**1**
13	List the variational methods.	**2**	**CO1**	**1**
14	State the three phases of finite element method.	**2**	**CO1**	**1**
15	Write the advantages and disadvantages of FEA.	**2**	**CO1**	**1**
Q. No.	**Part – B (16 Marks)**	**Marks**	**CO1**	**BL**
1	The following differential equation is available for a physical phenomenon $AE\frac{d^2y}{dx^2} + q_0 = 0$ with boundary conditions y (0) = 0 and $\frac{dy}{dx}_{x=L} = 0$ Find the value of f(x) using weighted residual method.	**16**	**CO1**	**1**
2	The governing differential equation for the fully developed laminar is given by $\mu\frac{d^2y}{dx^2} + \rho g\ cos\Theta = 0$ If boundary conditions $\frac{dy}{dx}]_{x=0} = 0$ u (L) = 0. Find the velocity distribution u(x).	**16**	**CO1**	**1**
3	The following differential equation is available for a physical phenomenon. $\frac{d^2u}{dx^2} + 50 = 0,\ 0\leq x \leq 20$ The trail function is y = a x (x – 10) Boundary conditions are y (0) = 0 y (10) = 0 find the value of 'a' by the following methods. (i). Point Collocation; (ii). Subdomain collocation.	**16**	**CO1**	**1**
4	The differential equation of a physical phenomenon is given by, $\frac{d^2u}{dx^2} + 500x^2 = 0,\ 0\leq x \leq 1$ Trial function, y = a_1 (x – x^4) Boundary conditions are y (0) = 0 y (1) = 0 Calculate the value of the parameter a_1 by the following methods: (i). Point Collocation; (ii). Least Squares	**16**	**CO1**	**3**
5	Find the solution for the following differential equation $EI\frac{d^4y}{dx^4} - q_0 = 0.$ The boundary conditions u (0) = 0 and $\frac{du}{dx}(0) = 0$	**16**	**CO1**	**1**

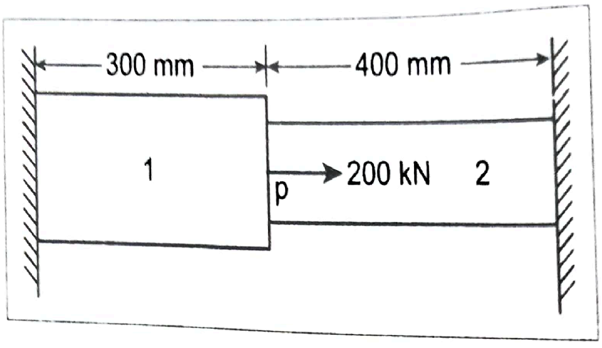
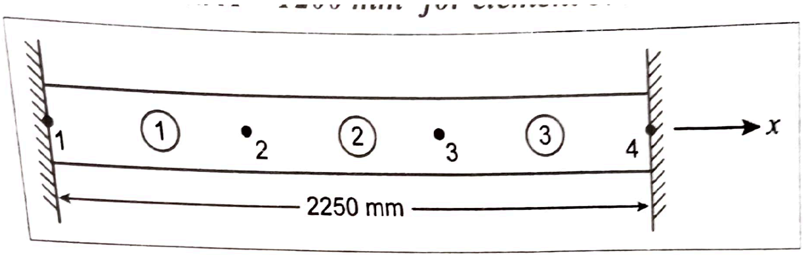
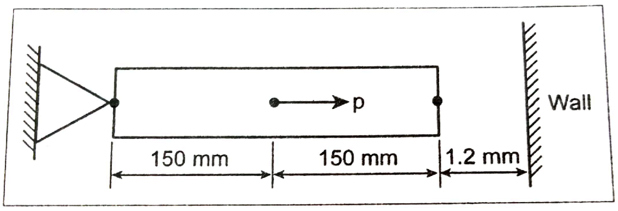
	$\frac{d^2u}{dx^2}(L) = 0 \quad \frac{d^3u}{dx^3}(L) = 0$			
6	The following differential equation is available for a physical phenomenon. $\frac{d^2u}{dx^2} + 50 = 0, \; 0 \leq x \leq 10$ The trail function is $y = a_1 x (10 - x)$. Boundary conditions are y (0) = 0 y (10) = 0 find the value of ‘a1’ by the following methods. (i). Point Collocation; (ii). Subdomain collocation; (iii). Least squares; (iv). Galerkin.	**16**	**CO1**	**1**
7	The following differential equation is available for a physical phenomenon. $\frac{d^2u}{dx^2} + 100 = 0, \; 0 \leq x \leq 10$ Boundary conditions are y (0) = 0 y (10) = 0 find the value of ‘a1’ by the following methods. (i). Point Collocation; (ii). Subdomain collocation; (iii). Least squares; (iv). Galerkin.	**16**	**CO1**	**1**
8	The differential equation of physical phenomenon is given by $\frac{d^2y}{dy^2} + 500x^2 = 0, \; 0 \leq x \leq 1$ By using trial function, $y = a_1(x - x^3) + a_2 (x - x^5)$, calculate the value of the parameters a_1 and a_2 by using any two weighted residual method.	**16**	**CO1**	**3**
	A bar of uniform cross section is clamped at one end and left free at the other end and is subjected to a uniform load ‘P’ axially as shown in figure. Calculate the displacement and stresses in the bar using two terms polynomial.  			
9	A bar of uniform cross section is clamped at one end and left free at the other end and is subjected to a uniform load ‘P’ axially as shown in figure. Calculate the displacement and stresses in the bar using three terms polynomial.  			**3**

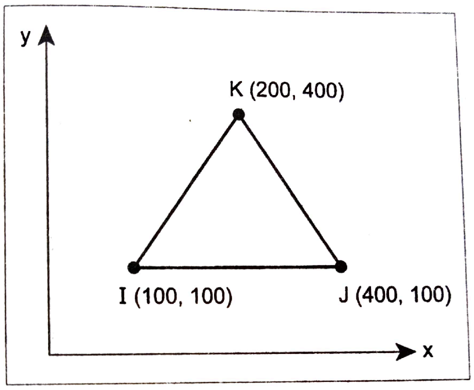
Unit II: ANALYSIS OF ONE DIMENSIONAL ELEMENTS

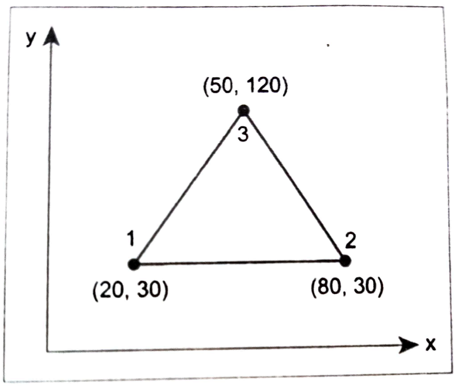
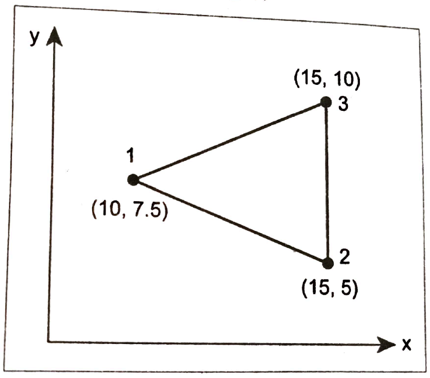
Q. No.	Part – A (2 Marks)	Marks	CO	BL
1	What are the types of problems treated as one dimensional problem?	2	CO2	1
2	Define normal mode.	2	CO2	1
3	List the types of dynamic analysis.	2	CO2	1
4	List out the properties of stiffness matrix.	2	CO2	1
5	Why are the polynomial terms are preferred for shape functions in finite element method?	2	CO2	1
6	Define shape function.	2	CO2	1
7	Write the shape function for one dimensional 2 noded element.	2	CO2	1
8	Write down the general finite element equation.	2	CO2	1
9	Determine the element mass matrix for one dimensional dynamic structural analysis problem. Assume two noded linear element.	2	CO2	1
10	What is meant by dynamic analysis?	2	CO2	1
11	Draw the shape function of a two noded line element.	2	CO2	1
12	Write the expression for stiffness matrix for truss element.	2	CO2	1
13	State the assumptions made while finding the force in a truss.	2	CO2	1
14	Write the stiffness matrix equation for 1 – D heat conduction element.	2	CO2	1
15	Name the boundary conditions involved in any heat transfer analysis.	2	CO2	1
Q. No.	**Part – B (16 Marks)**	**Marks**	**CO**	**BL**
1	One dimensional bar is shown in fig. Cross sectional area of the bar is 750 mm^2 and young's modulus is 2 X 10^5 N/mm^2. If u_1 = 0.5 mm and u_2 = 0.625, calculate the following: (i). Displacement at point 'P' (ii). Stress 'σ' (iii). Strain 'e' (iv). Element Stiffness Matrix (K) and Strain Energy (U) 	16	CO2	3
2	A steel bar of uniform length 800 mm is subjected to an axial load of 3 kN as shown in fig. calculate the elongation of the bar, neglecting self-weight.	16	CO2	3

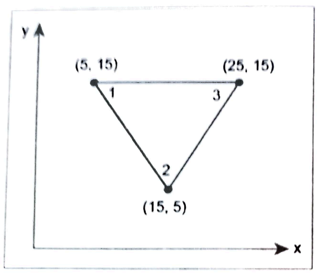
				
3	A thin plate of uniform thickness 25 mm is subjected to a point load of 420 N at mid-point as shown in fig. the plate is also subjected to self-weight. If young's modulus E = 2 X 10^5 N/mm^2 and unit weight density = 0.8 X 10^{-4} N/mm^3. Calculate i. Displacement at each nodal point. ii. Stresses in each element. 	**16**	**CO2**	**3**
4	Consider a taper steel plate of uniform thickness, t = 25 mm as shown in fig. The Young's modulus of the plate E = 2 X 10^5 N/mm^2 and weight density, ρ = 0.82 X10^{-4} N/mm^3. In addition to its self-weight, the plate is subjected to a point load p = 100 N at its mid-point. Calculate the following by modelling the plate with two finite elements: (i). Global force vector {F} (ii). Global stiffness matrix [K] (iii). Displacements in each element. (iv). Stresses in each element (v). Reaction force at the support	**16**	**CO2**	**3**

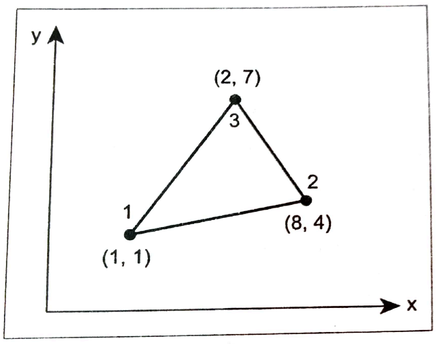
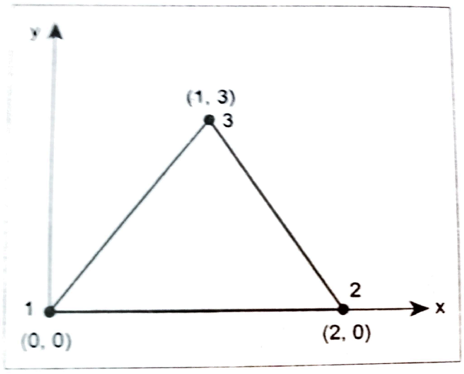
				
5	For a tapered plate of uniform thickness, t = 15 mm as shown in fig. find the displacements at the nodes by forming into two element model. The bar has a mass density ρ = 7800 kg/m^3, Young's modulus of the plate E = 2 X 10^5 MN/m^2. In addition to its self-weight, the plate is subjected to a point load p = 10 kN at its centre. Also find the reaction force at the support. 	**16**	**CO2**	**3**
6	Consider a bar as shown in fig. an axial load of 200 kN is applied at point p. take A_1 = 2400 mm^2, E1 = 70 X 10^9 N/mm^2, A_2 = 600 mm^2, E_2 = 200 X 10^{9}N/m^2. Calculate the following: (a) The nodal displacement at point p. (b) Stress in each material. (c) Reaction force.	**16**	**CO2**	**3**

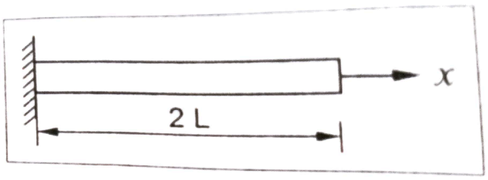
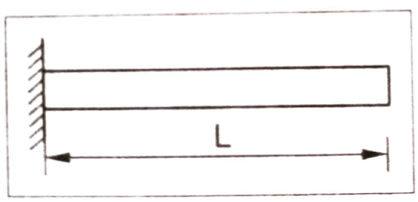
				
7	The three-bar assemblage is shown in fig. A force of 2500 N is applied in the x – direction at node 2. The length of each element is 750 mm. Take E = 4 X 10^5 N/mm^2 and A = 600 mm^2 for elements 1 and 2. Take E = 2 X 10^5 N/mm^2 and A = 1200 mm^2 for elements 3. Nodes 1 and 4 are fixed. Calculate the nodal displacements at 2 and 3. 	**16**	**CO2**	**3**
8	A rod is subjected to an axial load of P = 600 kN is applied as shown in fig. Divide the domain into two elements. Determine the following. (a) The nodal displacement at point p. (b) Stress in each material. (c) Reaction force. Take A = 250 mm^2 and E = 2 X 10^5 N/mm^2. 	**16**	**CO2**	**3**
	Unit III: ANALYSIS USING TWO DIMENSIONAL ELEMENTS			
Q. No.	**Part – A (2 Marks)**	**Marks**	**CO**	**BL**
1	How do you define two dimensional element.	**2**	**CO3**	**1**
2	What are the basic two dimensional elements?	**2**	**CO3**	**1**
3	Define LST element.	**2**	**CO3**	**1**

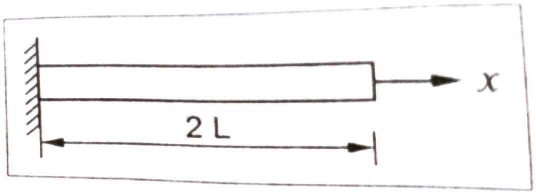
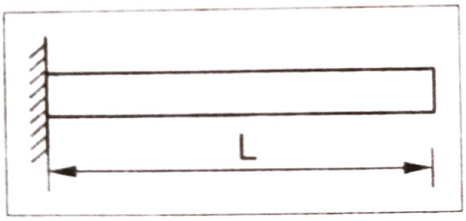
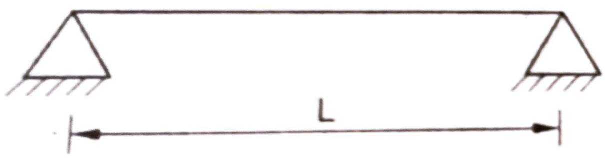
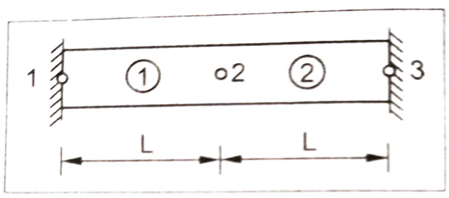
4	What is CST element?	**2**	**CO3**	**1**
5	What is QST element?	**2**	**CO3**	**1**
6	What is meant by plane stress analysis?	**2**	**CO3**	**1**
7	Define plain strain analysis.	**2**	**CO3**	**1**
8	Write a displacement funtion eqaution for CST element.	**2**	**CO3**	**1**
9	Write a strain – displacement matrix for CST element.	**2**	**CO3**	**1**
10	Write down the stress – strain relationship matrix for plane stress condition.	**2**	**CO3**	**1**
11	Write down the stress – strain relationship matrix for plane strain condition.	**2**	**CO3**	**1**
12	Write down the stiffness matrix equation for two dimensional CST element.	**2**	**CO3**	**1**
13	What are the difference between 2 dimensional scalar variable and vector variable elements?	**2**	**CO3**	**1**
14	Differentiate CST and LST element.	**2**	**CO3**	**1**
15	What do you mean by axisymmetric element?	**2**	**CO3**	**1**
Q. No.	**Part – B (16 Marks)**	**Marks**	**CO**	**BL**
1	For the constant strain triangular element (CST) shown in fig. Assemble strain – displacement matrix. Take t = 20 mm and E = 2 X 10^5 N/mm^2. 	**16**	**CO3**	**6**
2	Determine the stiffness matrix for the constant strain triangular (CST) element shown in fig. the coordinates are given in units of millimeters. Assume plane stress condition. Take E = 210 GPa, γ = 0.25 and t = 10 mm.	**16**	**CO3**	**4**

<table>
<tr><td></td><td>
</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Calculate the element stresses σ_x, σ_y, τ_{xy}, σ_1 and σ_2 and the principle angle Θ_P for the element shown in fig.


Nodal displacements are
u_1 = 2.0 mm, v_1 = 1.0 mm, u_2 = 0.5 mm, v_2 = 1.0 mm, u_3 = 2.0 mm and v_3 = 1.0 mm.
take E = 2.1 X 105 N/mm2 and γ = 0.25</td><td>16</td><td>CO3</td><td>3</td></tr>
<tr><td>4</td><td>For the plane strain element shown in fig, the nodal displacements are
u_1 = 0.005 mm; v_1 = 0.002 mm,
u_2 = 0.0 mm; v_2 = 0.0 mm,
u_3 = 0.005 mm; v_3 = 0.0 mm.
Determine the element σ_x, σ_y, τ_{xy}, σ_1 and σ_2 and the principle angle Θ_P. Let E = 70 GPa and γ = 0.3 and use unit thickmess for the plane strain. All coordinates are in millimeters.

</td><td>16</td><td>CO3</td><td>4</td></tr>
<tr><td>5</td><td>For the triangular element shown in fig., obtain strain displacement relation matrix [B] and dertemine the strains e_x, e_y and τ_{xy}.</td><td>16</td><td>CO3</td><td>4</td></tr>
</table>

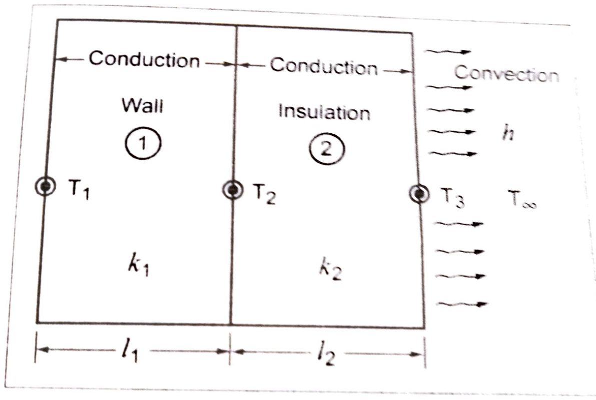
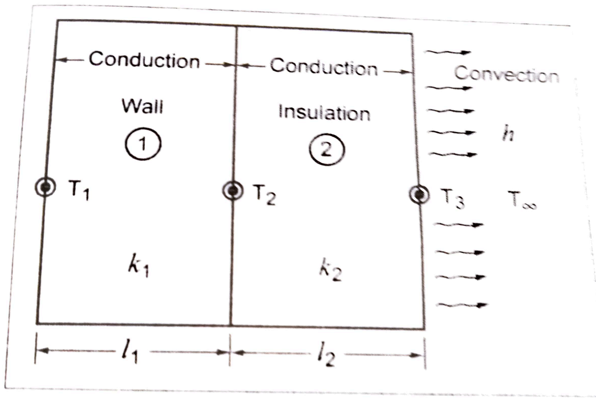
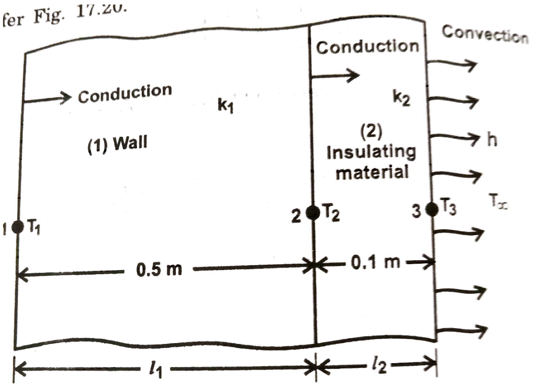
	 Nodal displacements are u_1 = 0.001 mm; v_1 = -0.004 mm, u_2 = 0.003 mm; v_2 = 0.002 mm, u_3 = - 0.002 mm; v_3 = 0.005 mm. All coordinates are in millimeteres.			
6	Calculate the element stiffness matrix and the temperarure force vector for the plane stress element shown in fig. the element exleriences a 20^0C increase in temperature. Assume coefficient of thermal expansion as $6X10^{-6}/^0$C.  Take, Young's modulus, E = 2X105 N/mm2 Poission's ratio γ = 0.25 and Thickness t = 5 mm.	**16**	**CO3**	**3**
Unit IV: DYNAMIC ANALYSIS				
Q. No	**Part – A (2 Marks)**	**Marks**	**CO**	**BL**
1	Define frequency of vibration and damping ratio.	**2**	**CO4**	**1**
2	Define longitudinal vibration and tranverse vibration.	**2**	**CO4**	**1**
3	Define magnification factor.	**2**	**CO4**	**1**
4	Write down the expression for longitudinal vibration for bar element.	**2**	**CO4**	**1**
5	Write down the expression for governing equation for free axial vibration of rod.	**2**	**CO4**	**1**
6	Write down the expression for governing equation for tranverse vibration of the beam.	**2**	**CO4**	**1**

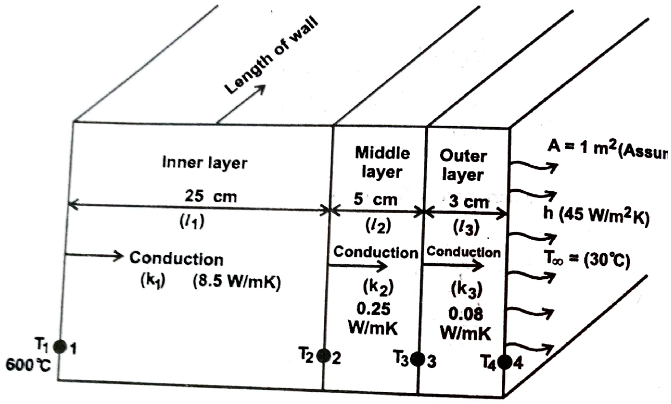
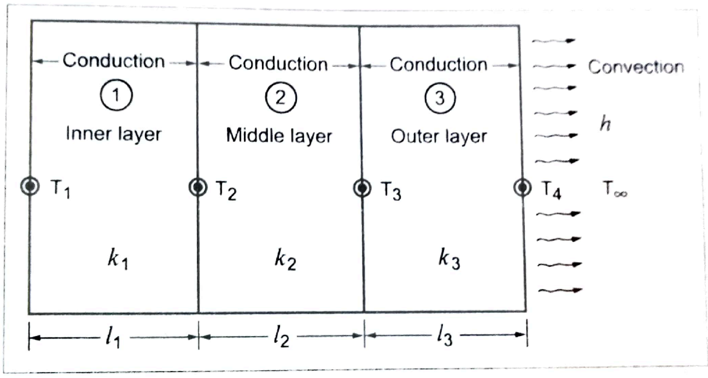
7	Write down the expression for tranverse vibration for beam element.	**2**	**CO4**	**1**
8	What are th types of Eigen value problems?	**2**	**CO4**	**1**
9	Define dynamic analysis.	**2**	**CO4**	**1**
10	What are the methods used for solving transient vibration problems?	**2**	**CO4**	**3**
11	Write down the equation for undamped system of Direct Integration Method in central difference method.	**2**	**CO4**	**1**
12	State the difference between direct and iterative methods for solving system of equations.	**2**	**CO4**	**1**
13	Define linear independence and independence of vectors.	**2**	**CO4**	**1**
14	Show that the matrix A = is orthogonal.	**2**	**CO4**	**1**
15	Prove that the vectors (1, 4, -2), (-2, 1, 3) and (-4, 11, 5) are linearly dependent.	**2**	**CO4**	**1**
Q. No.	**Part – B (16 Marks)**	**Marks**	**CO**	**BL**
1	For the bar shown in figure with 2L, modulus of elasticity E, mass density ρ, and cross section area A, determine the first two frequencies using lumped mass matrix. 	**16**	**CO4**	**4**
2	Consider a uniform cross section bar shown in figure of length "L" made up of a material whose young's modulus and density are given by E and ρ. Estimate natural frequencies of axial vibration of the bar using lumped mass matrix 	**16**	**CO4**	**5**
3	For the bar shown in figure with 2L, modulus of elasticity E, mass density ρ, and cross section area A, determine the first two frequencies using consistent mass matrix.	**16**	**CO4**	**4**

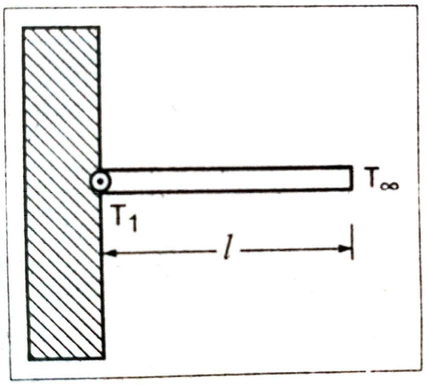
				
4	Consider a uniform cross section bar shown in figure of length "L" made up of a material whose young's modulus and density are given by E and ρ. Estimate natural frequencies of axial vibration of the bar using consistent mass matrix 	**16**	**CO4**	**5**
5	Consider a simply supported beam shown in figure. Let the length L = 1 m, E = 2 X 10^{11} N/m^2, Area of cross section A = 30 cm^2, Moment of inertia I = 100 mm^4, Density = 7800 kg/m^3. Determine the natural frequency using the lumped mass matrix. 	**16**	**CO4**	**4**
6	Determine the natural frequency of vibration using lumped mass matrix for a beam fixed at both ends as shown in figure. The beam has mass density of ρ, modulus of elasticity E, cross sectional area A, moment of inertia I. For simplicity of the long hand calculation, beam is discretized into two elements of length "L". 	**16**	**CO4**	**4**

Unit V: HEAT TRANSFER AND FLUID FLOW ANALYSIS

Q. No	Part – A (2 Marks)	Marks	CO	BL
1	List the different modes of heat transfer.	2	CO5	1
2	Write down the stiffness matrix equation for the on edimensional heat conduction element.	2	CO5	1
3	Write down the expression of shape funtion N and temperature funtion T for one dimensional heat conduction element.	2	CO5	1
4	Write down the finite element equation for one dimensional heat conduction with free end convection.	2	CO5	1
5	Write down the governing equation for two dimensional heat conduction.	2	CO5	1
6	Write down the shape function for two dimensional heat transfer.	2	CO5	1
7	Write down the stiffness matrix in two dimensional heat conduction and convection.	2	CO5	1
8	Define element capacitance matrix for unsteady state heat transfer problems.	2	CO5	1
9	Write analogies between structural and heat transfer.	2	CO5	1
10	What is steady state heat transfer and write its governing equation.	2	CO5	1
11	Write down the governing equation for two dimensional steady state heat conduction.	2	CO5	1
12	Write down thw expression for governing equation in 2 -D fluid mechanics.	2	CO5	1
13	Write down thw expression for shape function for 2 -D fluid mechanics.	2	CO5	1
14	Write down thw expression for stiffness matrix in 2 -D fluid mechanics.	2	CO5	1
15	Write down thw expression for velocity gradient in fluid mechanics.	2	CO5	1
Q. No.	**Part – B (16 Marks)**	**Marks**	**CO**	**BL**
1	A wall of 0.75 m thickness having thermal conductivity of 2.2 W/m K. The wall is to be insulated with a material of thickness 1 m having an average thermal conductivity of 0.5 W/m K. The inner surface temperature is 900^0C and outside of the insulation is exposed to atmospheric air at 30^0C with heat transfer coefficient of 40 W/m^2 K. Calculate the nodal temperatures.	16	CO5	3

				
2	A wall of 0.6 m thickness having thermal conductivity of 1.2 W/m K. The wall is to be insulated with a material of thickness 0.06 m having an average thermal conductivity of 0.3 W/m K. The inner surface temperature is 1000^0C and outside of the insulation is exposed to atmospheric air at 30^0C with heat transfer coefficient of 35 W/m^2 K. Calculate the nodal temperatures. 	**16**	**CO5**	**3**
3	A wall of 0.5 m thickness having thermal conductivity of 6 W/m K. The wall is to be insulated with a material of thickness 0.1 m having an average thermal conductivity of 0.3 W/m K. The inner surface temperature is 1200^0C and outside of the insulation is exposed to atmospheric air at 30^0C with heat transfer coefficient of 40 W/m^2 K. Calculate the nodal temperatures. fer Fig. 17.20. 	**16**	**CO5**	**3**
4	A furnace wall made up of three layers, inside layer with thermal conductivity 8.5 W/m K, the middle layer with conductivity 0.25 W/m K, the outer layer with conductivity 0.08 W/ m K. The respective thickness of the	**16**	**CO5**	**4**

	inner, middle and outer layer are 25 cm, 5 cm and 3 cm respectively. The inside temperature of the wall is 600^0C and outside of the wall is exposed to atmospheric air at 30^0C with heat transfer coefficient of 45 W/m^2 K. Determine the nodal temperature. 			
5	A furnace wall is made up of three layers, inside layer with thermal conductivity 7.5 W/m K, the middle layer with thermal conductivity 0.35 W/m K and the outer layer with thermal conductivity 0.01 W/m K. the respective thickness of the inner, middle and outer layer are 30 cm, 8 cm and 4 cm respectively. The inside temperature of the wall is 700^0C and outside temperature of the wall is exposed to atmosphere. with heat transfer coefficient of 40 W/m^2 K. Determine the nodal temperature. 	**16**	**CO5**	**4**
6	An aluminum alloy fin of 7 mm thick and 50 mm long protrudes from a wall which is maintained at1200C. The ambient air temperature is 220C. The heat transfer coefficient and thermal conductivity of the fin material are 140 W/m K and 55 W/m K respectively. Determine the temperature distribution of fin.	**16**	**CO5**	**4**

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