MAE 456 FINITE ELEMENT ANALYSIS
EXAM 1 Practice Questions

Name: ________________________ You are allowed one sheet of notes.

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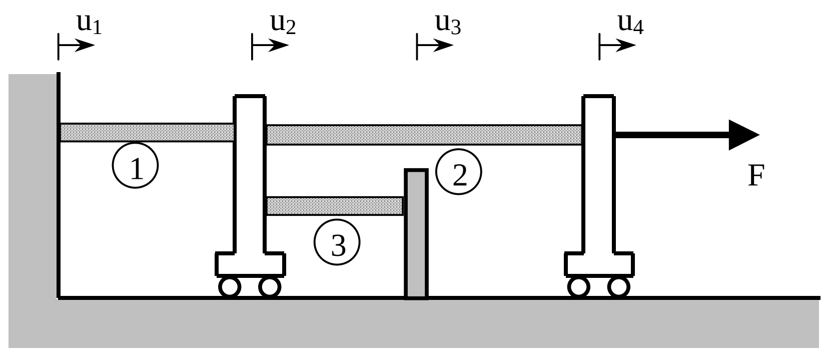
1. For the one-dimensional problem shown, calculate:
   a. The global stiffness matrix before the application of boundary conditions.
   b. The reduced stiffness matrix after the application of boundary conditions.

k_1 = 10,000 N/mm
k_2 = 5,000 N/mm
k_3 = 10,000 N/mm
F = 500 N



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2. Give the correct order for the following FEA tasks, considering both how SolidWorks works and the current best practices.

Step		
1	a.	Add Boundary Conditions
2	b.	Solve for displacements
3	c.	Visualize the results
4	d.	Solve for strains
5	e.	Create the mesh
6	f.	Create geometry
7	g.	Anticipate physical behavior, possibly using check calculations
8	h.	Determine whether FEA is warranted
9	i.	Solve for stresses

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3. In SolidWorks, explain what each of the following is for:

a. Simulation Manager

b. Fixture

c. Results

5

d. Probe

e. Post-Processing toolbar

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4. To what do DOF 1, DOF 2, … DOF 6 refer, when applying user-defined restraints in the Lab Assignments?

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5. What is the difference between truss (or rod or bar) elements and beam elements?

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6. What does the FEA software do when the yield stress is exceeded in a linear static analysis?

2

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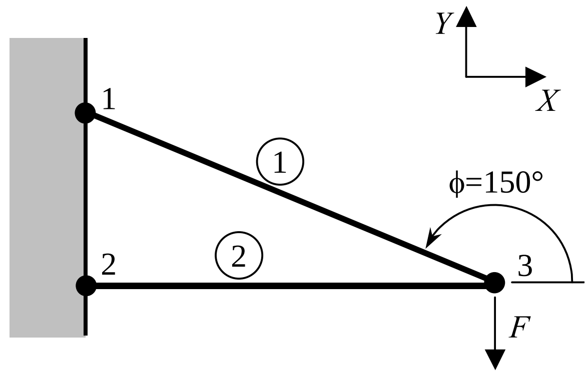
7. If an element has a quadratic shape function in x, will the strain also be a quadratic function of x?

2

8. Given the truss structure shown, calculate the stress and strain in truss element 1 if:

$A_1 = 0.0004 \text{ m}^2$
$E_1 = 200\text{x}10^9 \text{ Pa}$
$L_1 = 2 \text{ m}$

$$\mathbf{D} = \begin{Bmatrix} u_1 \\ v_1 \\ u_2 \\ v_2 \\ u_3 \\ v_3 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ -1\times10^{-3} \\ -2\times10^{-3} \end{Bmatrix}$$



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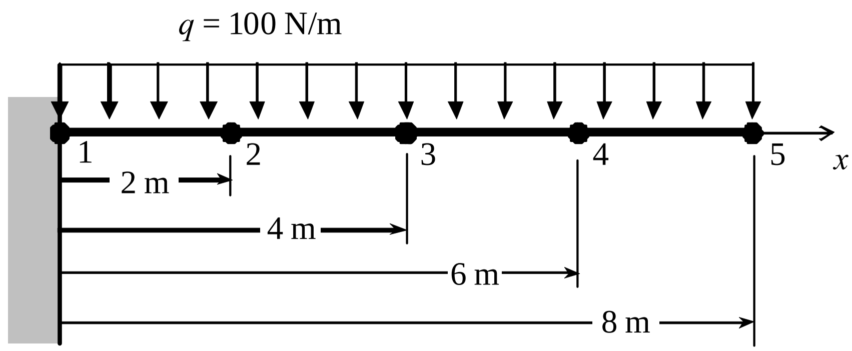
9. Give the equivalent nodal forces and moments that represent the distributed force on the beam shown. Give your answer in the form of the global force vector **R**.



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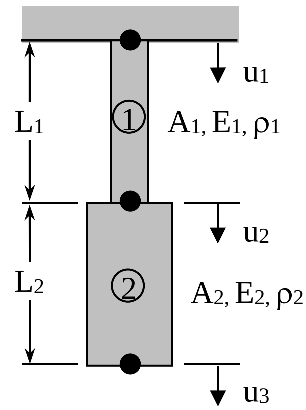
$$\mathbf{R} = \begin{Bmatrix} F_{1x} \\ F_{1y} \\ M_1 \\ F_{2x} \\ F_{2y} \\ M_2 \\ F_{3x} \\ F_{3y} \\ M_3 \\ F_{4x} \\ F_{4y} \\ M_4 \\ F_{5x} \\ F_{5y} \\ M_5 \end{Bmatrix} =$$

10. For the example on the right:
   - (i) Solve for the two elemental stiffness matrices.
   - (ii) Assemble the global stiffness matrix.
   - (iii) Compute the global applied force vector (**R**) considering only the gravitational force acting on the rod elements.
   - (iv) After applying the appropriate restraint condition(s), solve for the nodal displacements.
   - (v) Solve for the reaction force(s) at the restraint(s).
   - (vi) Solve for the element strains.
   - (vii) Solve for the element stresses.



$L_1 = L_2 = 1$ m
$A_1 = 0.001$ m^2
$A_2 = 0.004$ m^2
$E_1 = E_2 = 70 \times 10^9$ Pa
$\rho_1 = \rho_2 = 2700$ kg/m^3

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11. In Question 10, what is the displacement at the middle of element 1 (i.e., at 0.5 m from the top)?

4

12. Plot the displacement of both elements as a function of the distance from the top.

2

13. In Question 10, what is the strain at the middle of element 1 (i.e., at 0.5 m from the top)?

2

14. Plot the strain of both elements as a function of the distance from the top.

2

15. In Question 10, what is the stress at the middle of element 1 (i.e., at 0.5 m from the top)?

2

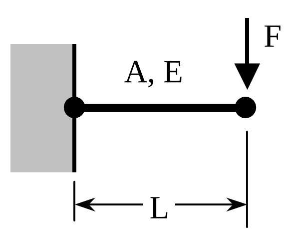
16. Plot the stress of both elements as a function of the distance from the top.

2

17. In the above questions, will the answers be the exact answers? If your answer is no, what aspect of the problem makes it so the FEA answer is not fully correct?

2

18. Consider the horizontal TRUSS element with cantilevered support conditions. Is the stiffness matrix singular (i.e., would you be able to solve for the displacements)?



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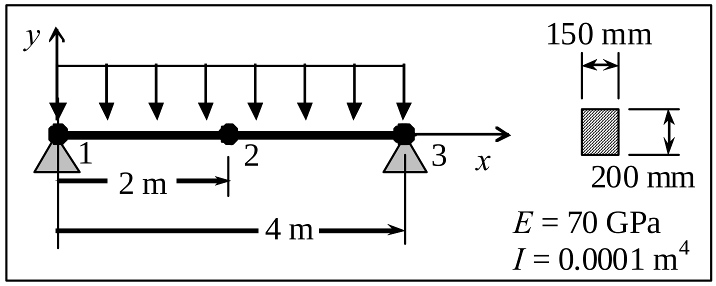
19. For the beam elements shown (with shape functions given below), the nodal displacements have been calculated in meters and radians as:

$$\mathbf{D} = \begin{Bmatrix} v_1 \\ \theta_1 \\ v_2 \\ \theta_2 \\ v_3 \\ \theta_3 \end{Bmatrix} = \begin{Bmatrix} 0 \\ -0.0076 \\ -0.010 \\ 0 \\ 0 \\ 0.0076 \end{Bmatrix}$$



a) Plot (sketch) the vertical displacement $v(x)$ for the entire beam (both elements).
b) Plot the angle of the beam $\theta(x)$ for the entire beam.
c) Plot the moment $M(x)$ carried by the beam for the entire beam.
d) Plot the stress $\sigma(x)$ at the bottom of the beam.
e) Plot the stress $\sigma(x)$ at the middle of the beam cross-section.

- In the plots, write actual values at node positions.
- Indicate the order of the polynomials for each plot.

Recall that for a beam element $v(x) = \mathbf{Nd}$, where:

$$\mathbf{N} = \left[1 - \frac{3x^2}{L^2} + \frac{2x^3}{L^3} \quad x - \frac{2x^2}{L} + \frac{x^3}{L^2} \quad \frac{3x^2}{L^2} - \frac{2x^3}{L^3} \quad -\frac{x^2}{L} + \frac{x^3}{L^2} \right] \text{ and } \mathbf{d} = \begin{Bmatrix} v_1 \\ \theta_1 \\ v_2 \\ \theta_2 \end{Bmatrix}$$

$$\theta(x) = \frac{dv}{dx}$$

$$M = EI\frac{d^2v}{dx^2} = EI\mathbf{Bd}, \text{ where: } \quad \mathbf{B} = \left[-\frac{6}{L^2} + \frac{12x}{L^3} \quad -\frac{4}{L} + \frac{6x}{L^2} \quad \frac{6}{L^2} - \frac{12x}{L^3} \quad -\frac{2}{L} + \frac{6x}{L^2} \right]$$

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Question 19 cont'd.

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