

Answer **3** of the 4 questions.

COMPUTER-AIDED ENGINEERING

Ph.D. QUALIFIER EXAM – Fall 2002

**THE GEORGE W. WOODRUFF SCHOOL OF MECHANICAL ENG.
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- All questions in this exam have a common theme: *Pedestrian Bridges*
- Answer **3** out of the 4 questions. Indicate which questions you want graded.
- Make suitable assumptions when data is not available or when you do not follow a question. State your assumptions clearly and justify.
- Show all steps and calculations.
- *During ORALS, you will be given an opportunity to tell us how CAE fits into your doctoral research. Please come prepared to make this opening statement.*

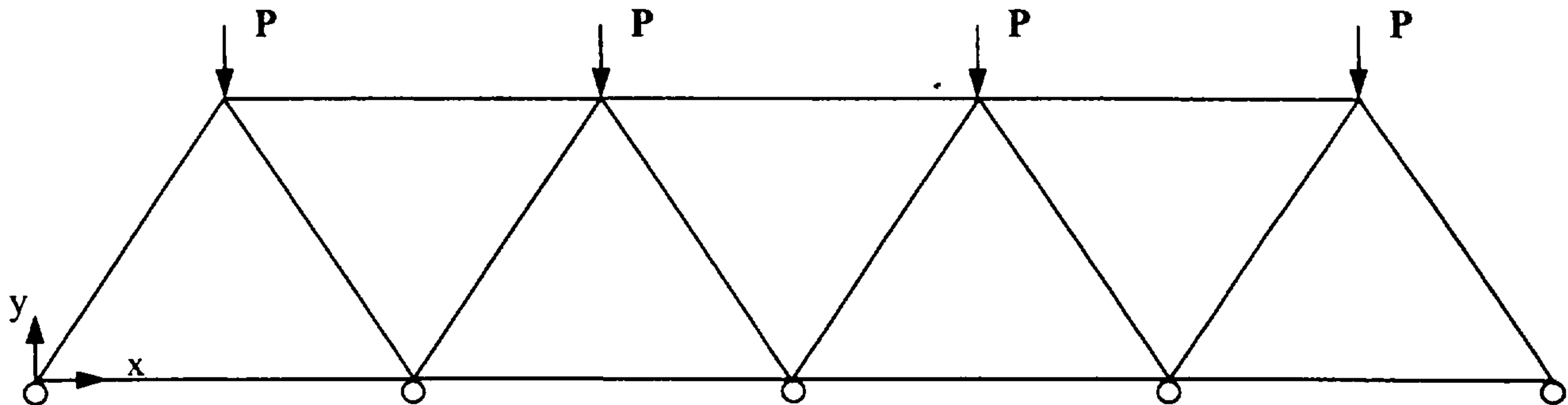
GOOD LUCK!

Answer 3 of the 4 questions.

Question 1

FINITE-ELEMENT MODELING OF BRIDGE STRUCTURE

Consider the structure shown below with the loading conditions. Assume that the structure consists of truss or rod members positioned as equilateral triangles as shown. Assume the all nodes are pivoted, and the structure is supported at the five points as shown as circles. Assume that all members are identical in terms of geometry and material.



You are asked to analyze the structure using finite-element formulation.

1. Use symmetry wherever possible.
2. Write down the individual stiffness matrix for the elements of interest.
3. Assemble the stiffness matrices and show the equation with the assembled stiffness matrix, displacement vector, and the force vector.
4. Identify the boundary conditions and loading conditions, and simplify the above equation. You need not solve.
5. Assume that the structure can be modeled using 7 *plane constant-strain triangle* elements. Sketch the shape functions for at least one plane constant-strain triangle element.

Element Stiffness Matrix

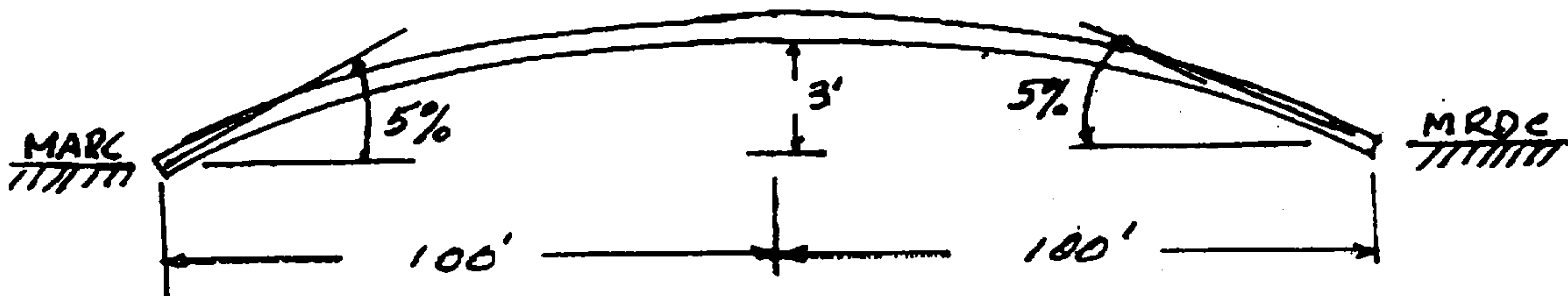
$$[K] = \frac{EA}{L} \begin{bmatrix} l^2 & lm & -l^2 & -lm \\ lm & m^2 & -lm & -m^2 \\ -l^2 & -lm & l^2 & lm \\ -lm & -m^2 & lm & m^2 \end{bmatrix} \quad \begin{aligned} l &= \frac{x_2 - x_1}{L} \\ m &= \frac{y_2 - y_1}{L} \end{aligned}$$

where E, A, and L are the Modulus of Elasticity, Area of cross-section, and Length of the element respectively; *l* and *m* are direction cosines of the element with respect to X and Y axes.

Answer 3 of the 4 questions.

Question 2
Geometric Modeling of Bridge Structure

The sketch shown below is an elevation view of a proposed walk bridge between MARC and MRDC. The bridge shape is to be modeled by parametric spline(s). The bridge is to be 200' long, of symmetric shape. The slope at each end is to be a maximum of 5%, and the maximum rise in the center is 3 feet. Develop both a cubic spline and bezier spline approach to modeling the shape, and discuss the assets and liabilities of each approach. You should select appropriate control points for each approach as needed.



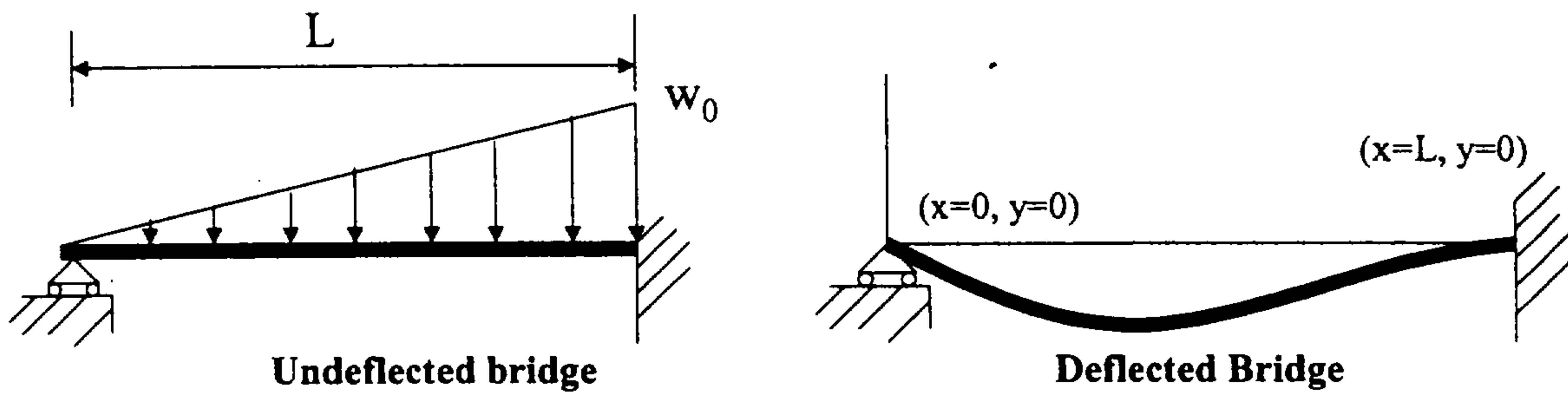
Answer 3 of the 4 questions.

Question 3

The figures below show the MARC bridge under loading when a class lets out from MRDC. The bridge is modeled as a uniform beam with a linearly increasing distributed load. An undergraduate student has defined the equation for the resulting elastic curve as follows:

$$y = w_0 (-x^5 + 2L^2x^3 - L^4x) / (120 E I L)$$

where $L = 180$ ft, $E = 29 \times 10^6$ lbs/inch², $I = 723$ inch⁴ and $w_0 = 144 \times 10^3$ lbs/ft

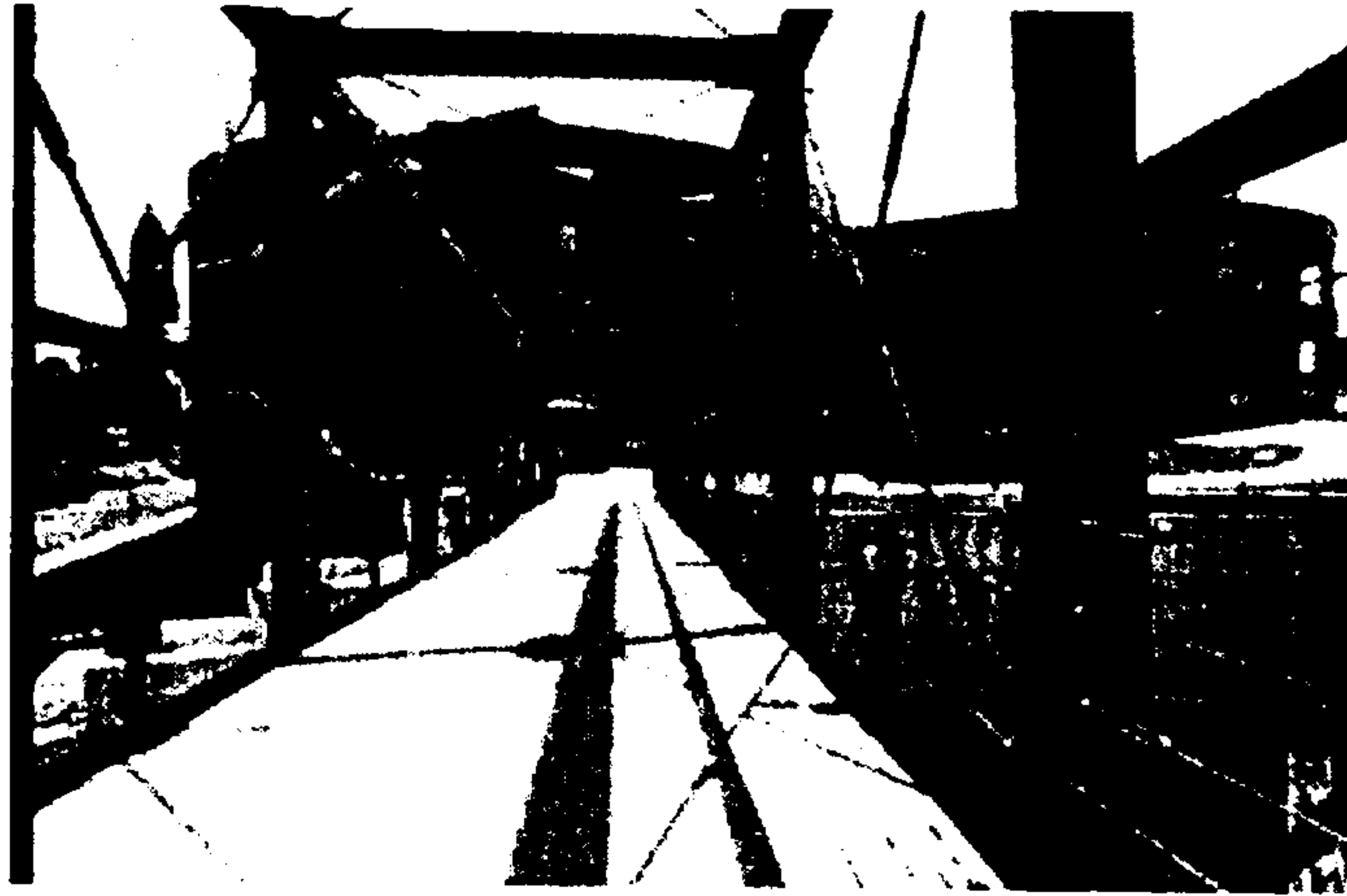


- Find the point at which the maximum deflection of the bridge occurs, as well as the amount of deflection using the Newton-Rapson root finding technique. Describe your assumptions and thought-process.
- Discuss whether the results make sense or not, and why.
- How would you model this beam using a finite element approach, and why?
- Describe at least three other root finding techniques in terms of how they work and their advantages and disadvantages.

Answer 3 of the 4 questions.

Question 4

Consider the walking bridge that connects the MARC and MRDC buildings (see the photo). As part of an advanced mechanics of materials course, a set of experiments is needed to measure the deflections of the bridge under various loading conditions. Assume that a large measurement system is available to generate a set of points on the bridge. This could take the form of a laser scanner, for example. Given a set of measured points (a point cloud), the experimenters need to fit surfaces to the points. This question deals with the surface fitting problem.



- Assume that only the bottom surface of the bridge is of interest. What types of surface patches would be appropriate to model deflected bridge shapes? Provide at least 3 types and explain why you believe they are appropriate.
- Explain the process of formulating a least-squares fitting problem. What is minimized? Explain how to formulate the minimization problem in light of the surface types you identified in part (a).
- Derive the equations for this least-squares surface fitting problem. I do not expect you to complete the derivation, but show how you would start the derivation, include the equation for the error term to be minimized, and describe the steps you would follow.
- Consider the linear fit to the 2-D points shown in the graph. The R^2 value is 0.9553. Is this a good fit? Explain your reasoning.

