GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - FALL Semester 2001

Computer-Aided Engineering
EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

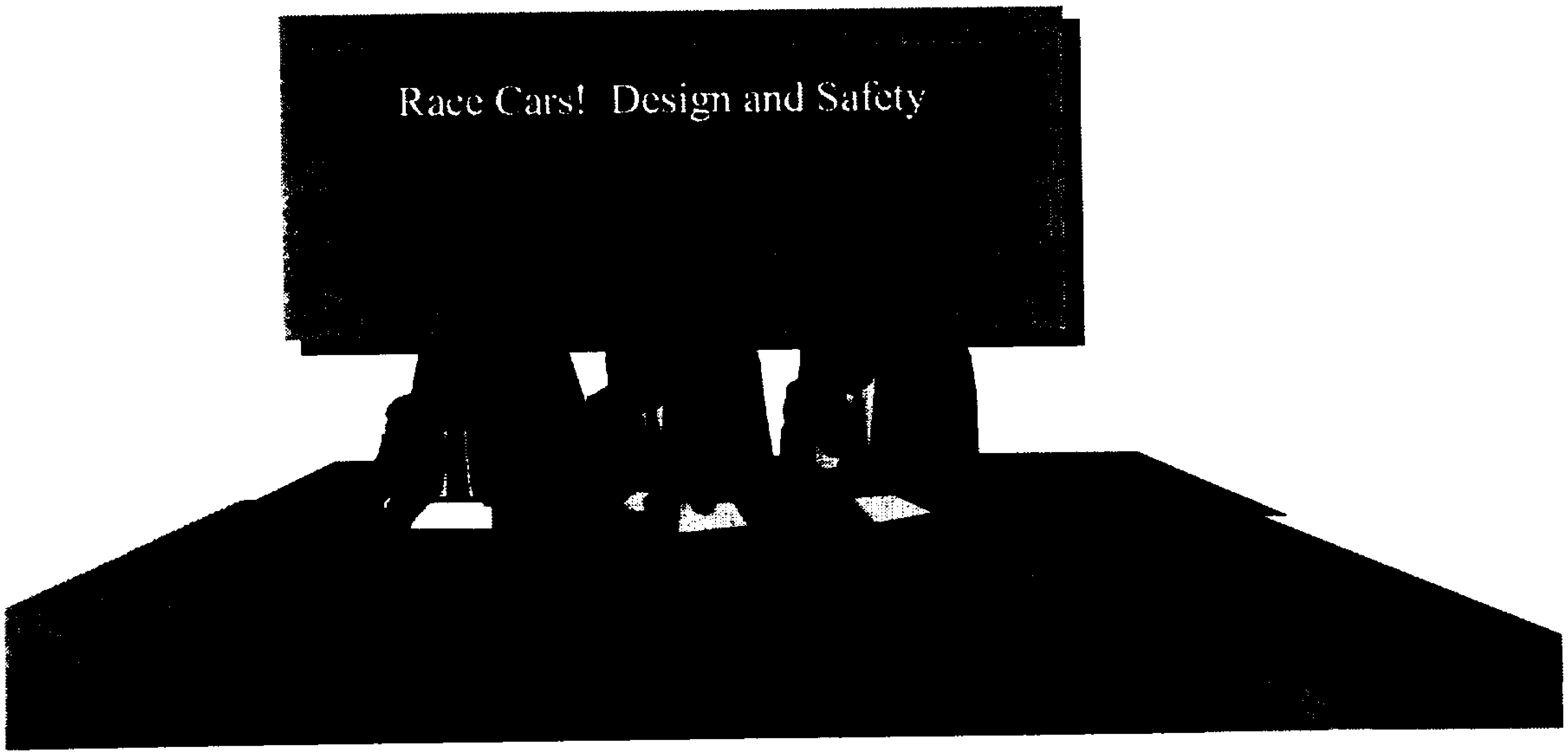
- **Please sign your name on the back of this page—**

COMPUTER-AIDED ENGINEERING

Ph.D. QUALIFIER EXAM – Fall 2001

THE GEORGE W. WOODRUFF SCHOOL OF MECHANICAL ENG.
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GA 30332-0405

Fulton, Bras, and Sitaraman (Chair)



- All questions in this exam have a common theme: ***Design and Safety of Race Cars***
- Answer all questions.
- 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!

Question 1

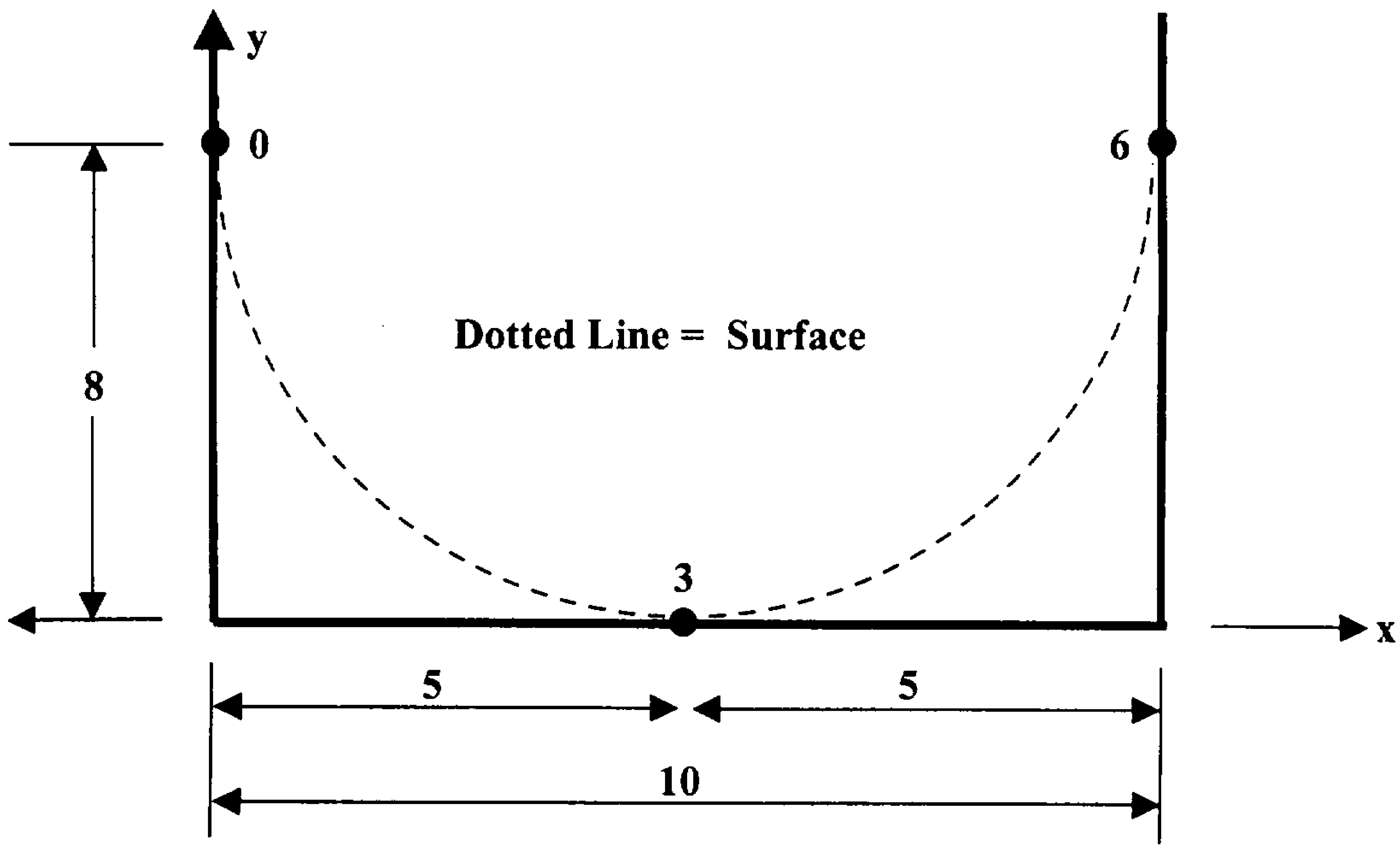
We are developing a model of the symmetric surface of a race car panel which is modeled by two Bezier segments as shown by the dotted line in the sketch below. The segments go from points 0 to 3 and 3 to 6 as shown. Points 0, 3, and 6 are control points for the surface, and the surface has the following conditions:

a) The shape must be vertical at points 0 and 6;

b) The two segments must have C1 continuity at point 3; and

c) Each segment is a 4-point Bezier spline with intermediate points selected by the designer.

1. Discuss the conditions required to model this panel with the two Bezier segments.
2. Select the location of the intermediate Bezier points to meet these criteria.
3. Express the formula for the various Bezier segments in terms of the key parameters and the specific points.
4. Define what would be different if the two segments were cubic splines.



Question 2

Figure 2.1 shows a structure from the race car. Assume that the structure is symmetric and the material is isotropic. A load of magnitude *P* acts on the structure as shown in the figure. Assume that the thickness of the structure is one order of magnitude smaller than the planar dimensions of the structure.

a) Select an appropriate element type to model the structure. Show the mesh and the boundary conditions. Use symmetry wherever possible.

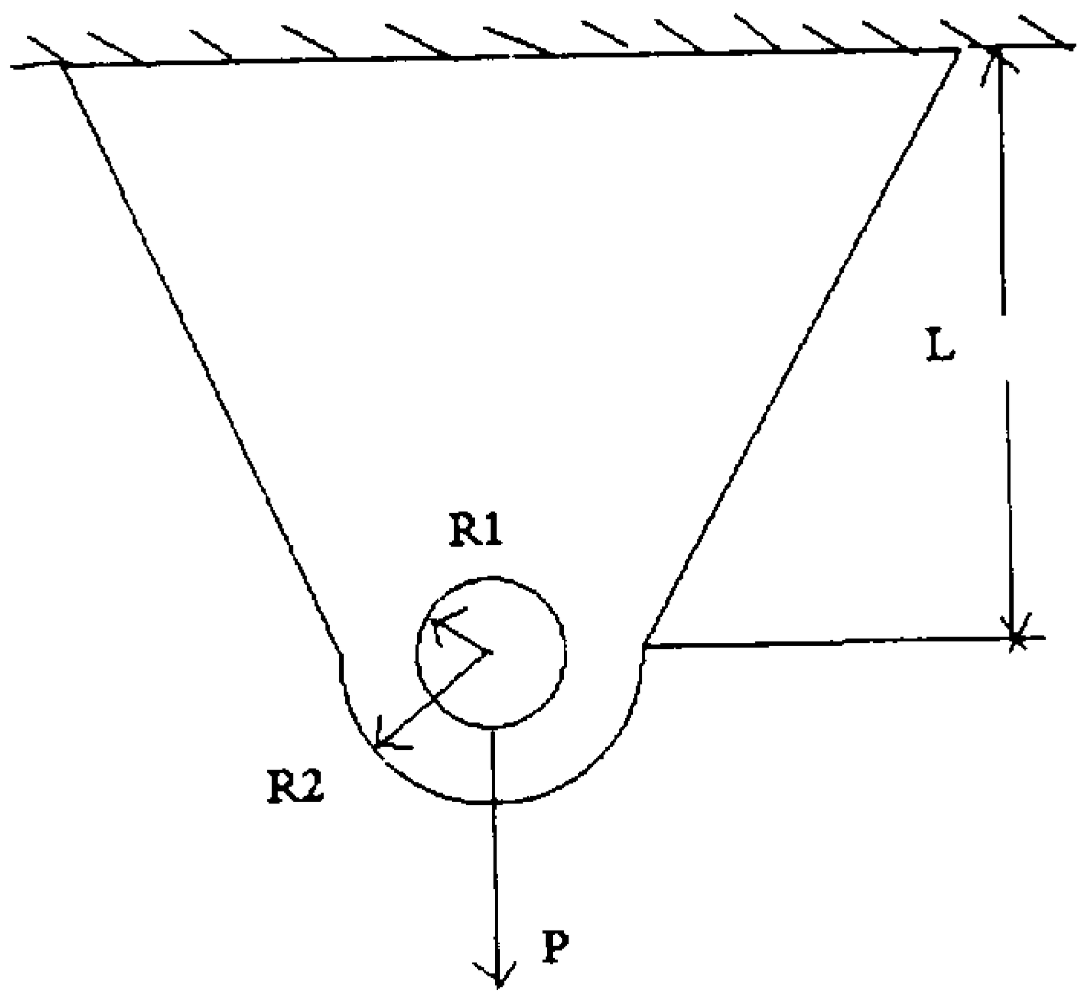


Figure 2.1

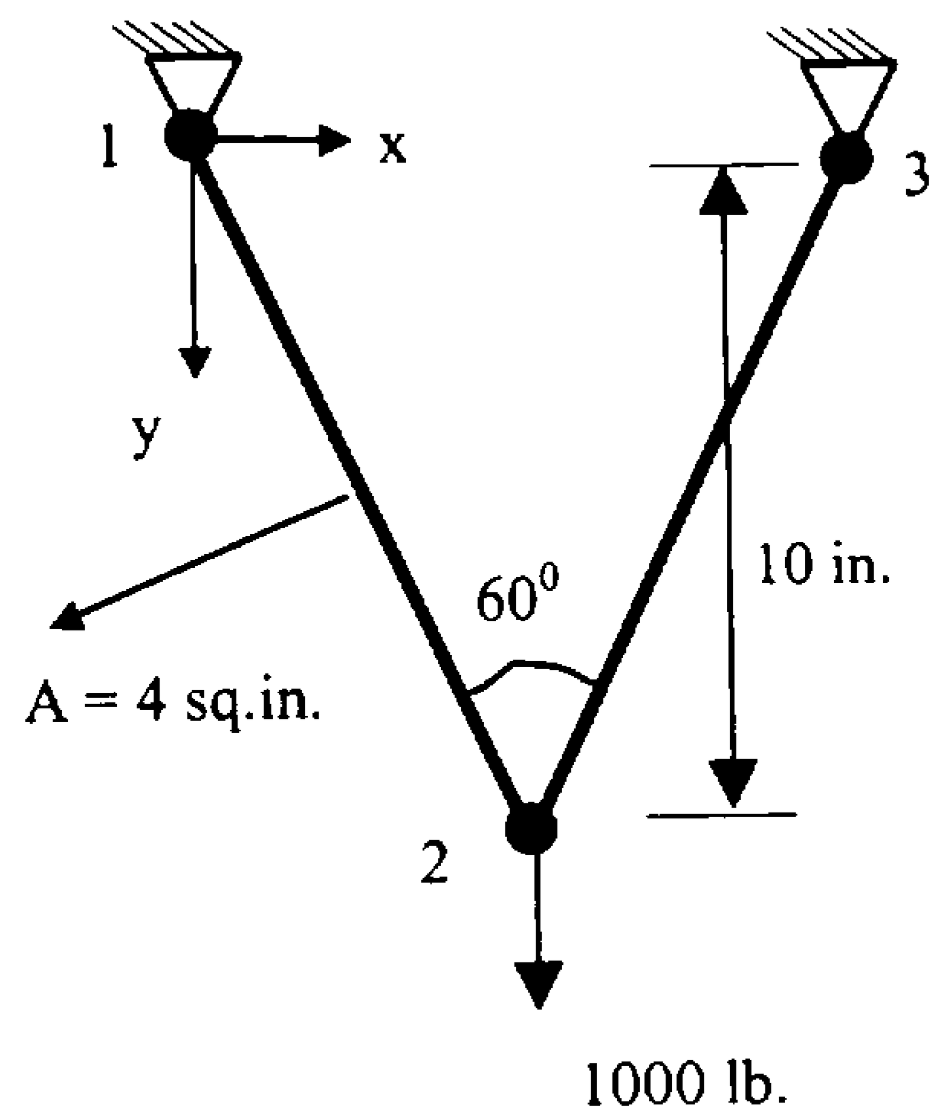


Figure 2.2

The structure in Figure 2.1may be simplified as the structure shown in Figure 2.2 where the members are pivoted. The height of the structure is 10 in., and the individual members have a cross-section area of 4 sq. in. The angle between the two members is 60°. A load of 1000 lb. is applied as shown in the figure. All members are made of the same material with $E = 30X10^6$ psi

You are asked to analyze the structure in Figure 2.2 using Finite-Elements.

b) **Use symmetry.** Assemble and show the global stiffness matrix, starting with individual element stiffness matrix.
c) Determine displacement at Node 2.
d) Compute the reaction force at Node 1.

1. ***Element Stiffness Matrix***

$$[K] = \frac{EA}{L}\begin{bmatrix} l^2 & lm & -l^2 & -lm \\ lm & m^2 & -lm & -m^2 \\ -l^2 & -lm & l^2 & lm \\ -lm & -m^2 & lm & m^2 \end{bmatrix}$$

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 and are given by:

$$l = \frac{x_2 - x_1}{L}$$

$$m = \frac{y_2 - y_1}{L}$$

Question 3

Spoiler Analysis

Part of the racecar design is an analysis of the new spoiler system. The spoiler's angle can be controlled during a race either remotely or by the driver. The spoiler's angle can be changed to almost 90 degrees to assist braking by acting like an airbrake.

The test-team is interested in calculating the work done by the spoiler during a run on a test-track.

F(x) is the force on the spoiler at position x and $\alpha(x)$ is the angle of the spoiler at position x.

$$W = \int_{x0}^{x1} F(x)d(x)$$

Further complexity is introduced if the angle between the force and the direction of movement also varies as a function of position. The resulting work equation that accounts for this effect is:

$$W = \int_{x0}^{x1} F(x)\cos[\alpha(x)]d(x)$$

The data gathered on the track is listed in the table below.

x	F(x)	α(x) in rad	F(x) cos[α(x)]
0	0.0	0.50	0.0000
5	9.0	1.40	1.5297
10	13.0	0.75	9.5120
15	14.0	0.90	8.7025
20	10.5	1.30	2.8087
25	12.0	1.48	1.0881
30	5.0	1.50	0.3537

a) Calculate the amount of work done by the spoiler using the trapezoidal rule. Use 3 segments.

b) It turns out, that compared to the actual analytical result, a two segment trapezoidal numerical integration is more accurate than a six segment trapezoidal numerical integration. Explain how this apparently counterintuitive result is possible.

c) Explain what Simpson's 3/8 rule is and how it works.

d) What are some other methods for numerical integration, and what are their advantages and disadvantages?