GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Spring Semester 2001

Computer-Aided Engineering
EXAM AREA

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

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

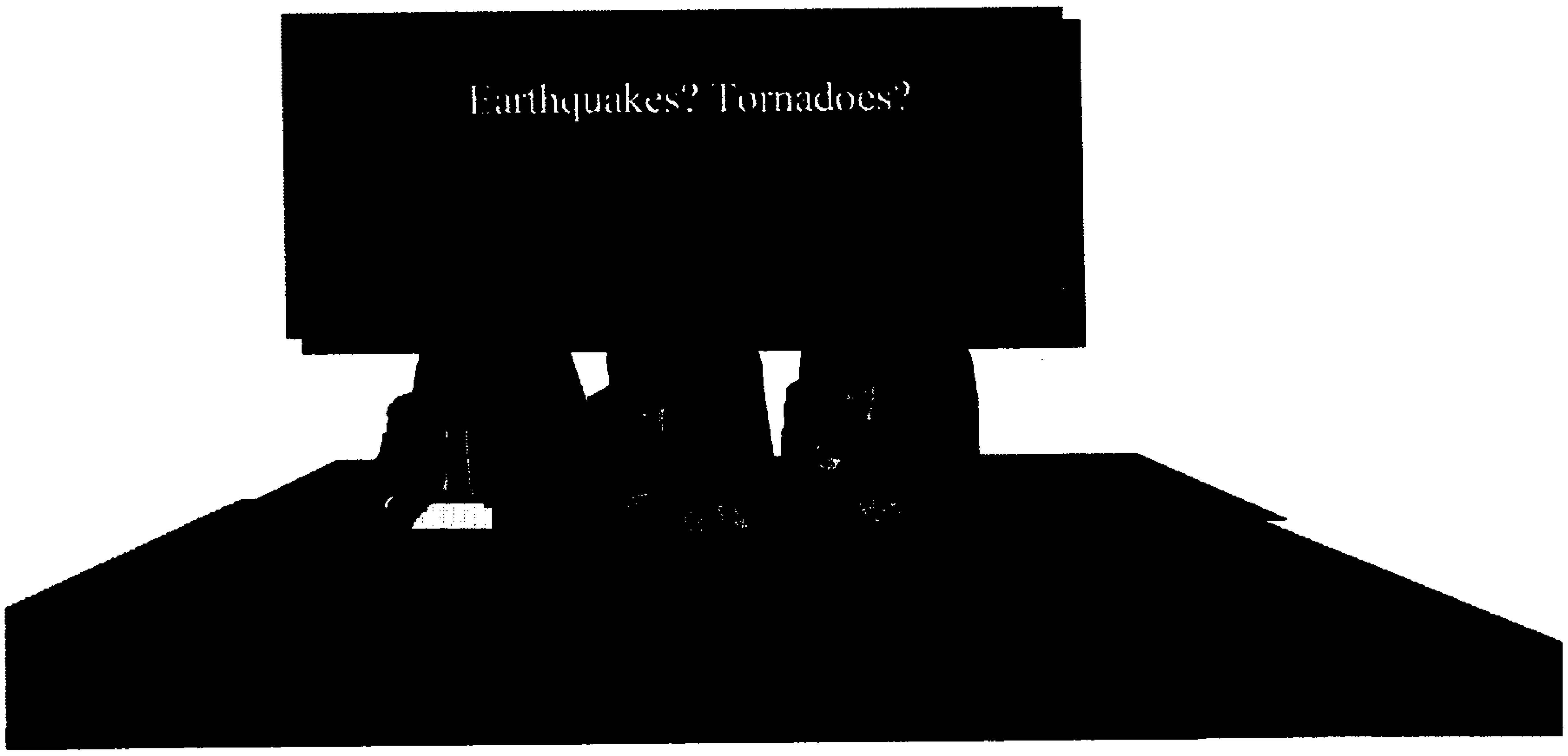
Please **p r i n t** your name here.

The Exam Committee will get a copy of this exam and will not be notified whose paper it is until it is graded.

COMPUTER-AIDED ENGINEERING
Ph.D. QUALIFIER EXAM – Spring 2001

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

Fulton, Rosen, and Sitaraman (Chair)



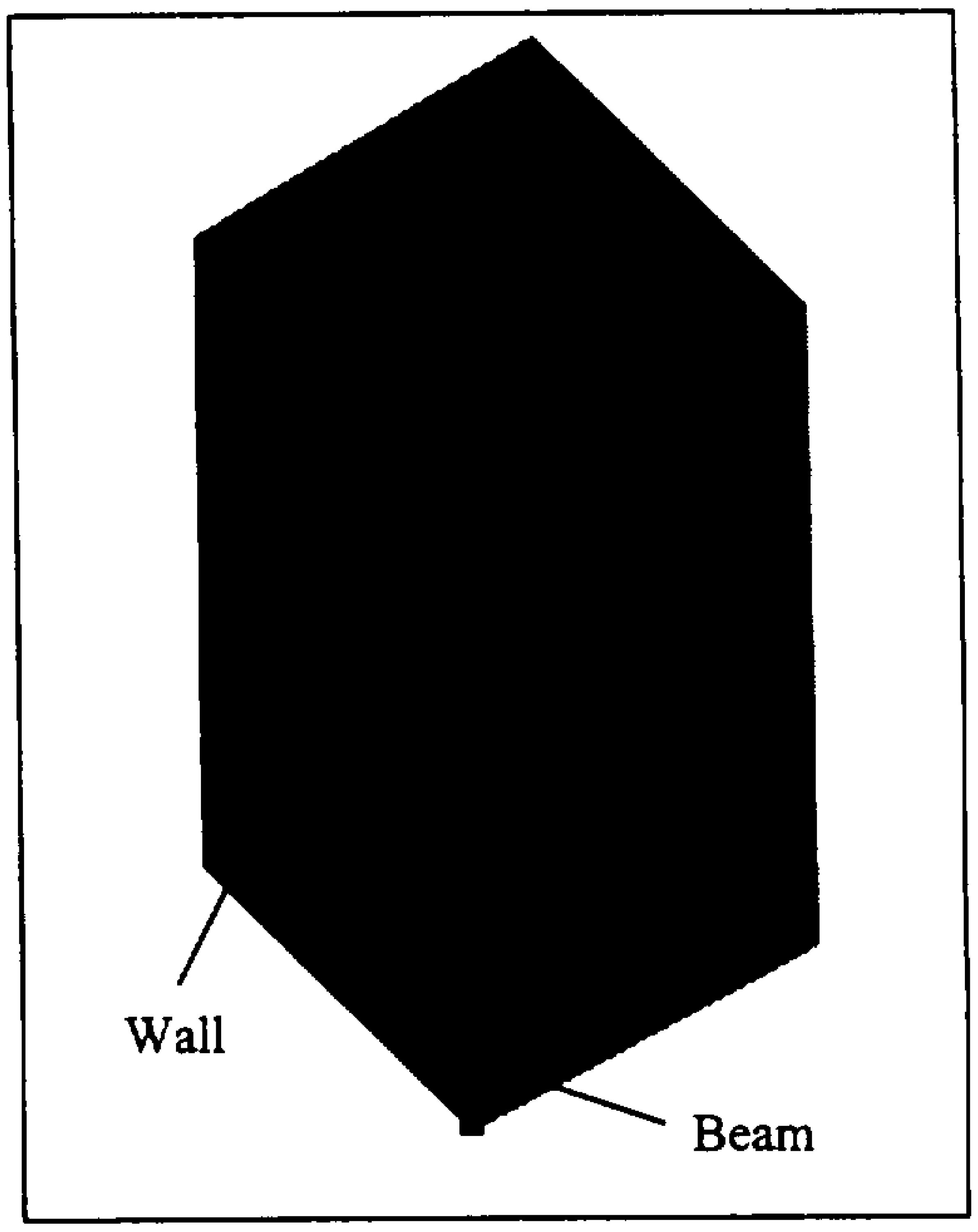
- All questions in this exam have a common theme: ***Design against Earthquake and Tornado Damage***.
- Answer all questions.
- Make suitable assumptions when data is not available or when you do not follow a question. State your assumptions clearly and justify.
- Show all steps and calculations.
- ***During 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

During an earthquake, buildings and other structures are subject to vibrations caused by the ground shaking. As a result, the shape of these buildings and structures changes rapidly. Assume that you are working on an earthquake simulator and it is your job to develop the visualization and animation module of the simulator. Of particular concern for this problem is the selection of a suitable geometric model (curves and surfaces) for buildings. The primary criteria for selecting geometric models are: accurately simulate building structure shapes during vibration, and very fast computations must be possible (shapes must be computed and displayed in real-time).

Consider the building schematic shown at right. Note the highlighted vertical beam and vertical wall.



Questions

a) Propose **three different types of curves** (e.g., cubic spline) that you could use to model the beam. For ONE of your proposed curve types, sketch three different curve shapes and illustrate how its shape is controlled (e.g., show control vertices or points that the curves passes through).

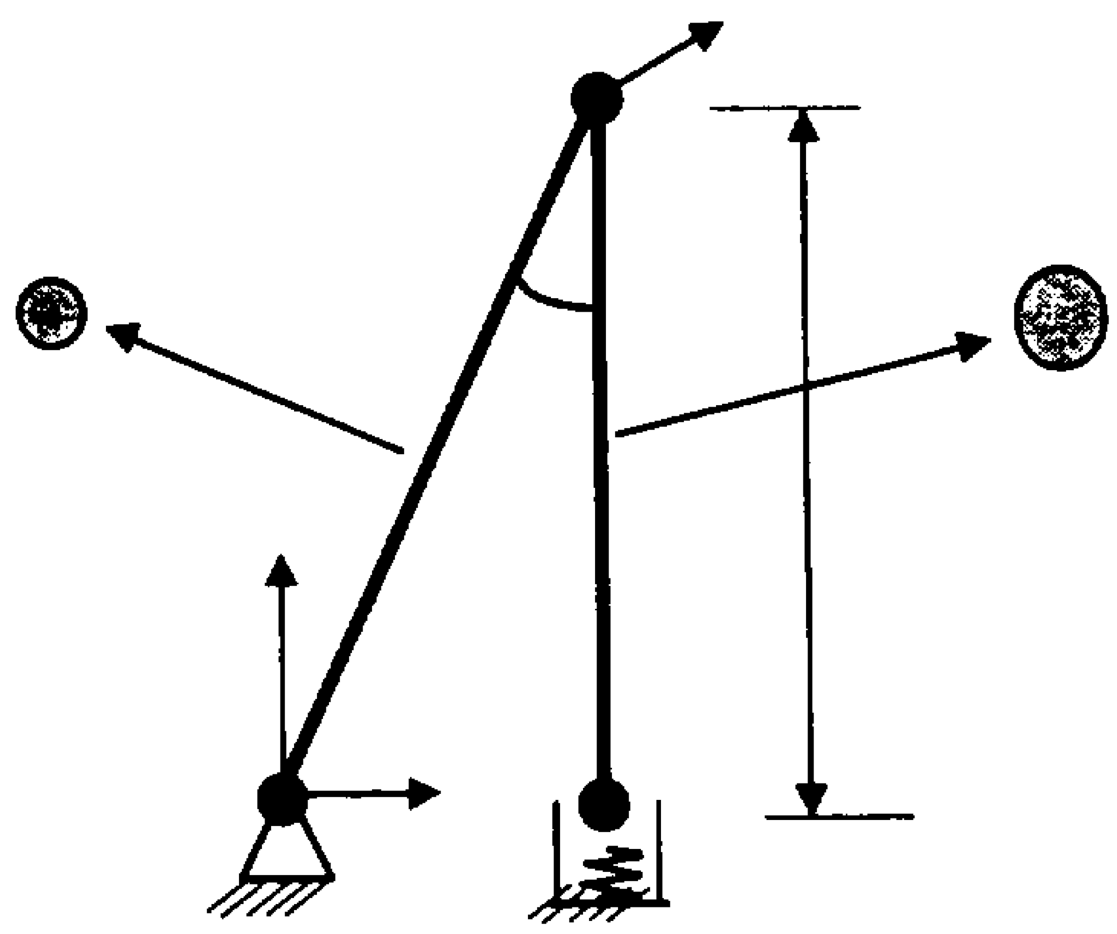
b) For EACH curve type, identify at least **three characteristics** that of that curve type that you believe makes it suitable for modeling earthquake-induced beam shapes.

c) In light of these characteristics, **evaluate** your three curve types using the selection criteria. Explain their advantages and disadvantages (at least 3 of each). Based upon your evaluations, which curve type would you select? Explain your reasoning.

d) Propose **three different types of surfaces** (e.g., 7^{th} order NURBS) that you could use to model the wall. Briefly identify at least **three characteristics** of that surface type that you believe makes it suitable for modeling earthquake-induced wall shapes.

Question 2

Figure below shows the end view of a truss structure. The members of the truss structure are pivoted and are supported as shown in the Figure. It is being thought that a spring with a stiffness of 12×10^6 lb/in may be added at the bottom of joint 3 to help reduce earthquake-induced damage. The spring is housed in a vertical cylindrical enclosure such that the ball at point 3 is constrained against horizontal movement. The bar that connects point 1 and 2 has a cross-section area of 12 sq. in. The bar that connects point 2 and 3 is 10 ft. long and has a cross-section area of 24 sq. in. The angle between the two bars is 30^0.



All bars are made of the same material with $E = 30 \times 10^6$ psi. The truss is supporting a load whose x component is *15,000 lb* and y component is *10,000 lb* at point 2 as shown in the Figure.

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

a) Assemble and show the global stiffness matrix, starting with individual element stiffness matrix.

b) Determine displacements at points 2 and 3.

c) Compute the load in the bar connecting point 2 and 3.

Element Stiffness Matrix

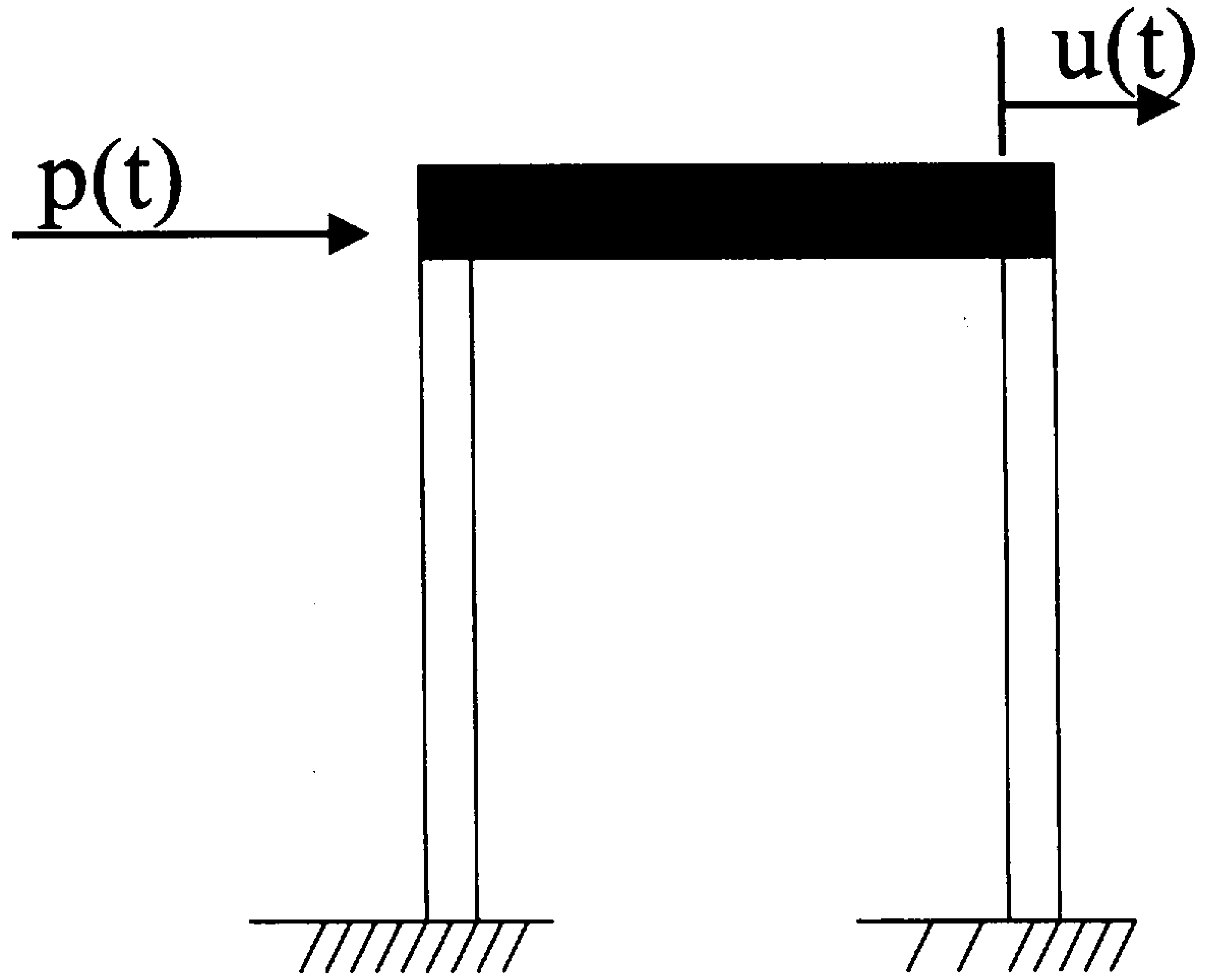
$$[K] = \frac{EA}{L}\begin{bmatrix} l^2 & lm & -l^2 & -lm \\ lm & m^2 & -lm & -m^2 \\ -l^2 & -lm & l^2 & lm \\ -lm & -m^2 & lm & m^2 \end{bmatrix}$$

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



The above building frame is anchored at the rigid base and is subjected to a wind force *p(t)*. In the above figure, *m* is the building mass, *u(t)* the lateral displacement of the mass and *k/2* the lateral stiffness of each of the columns. The equation of motion can be approximated by

$$m\ddot{u} + ku = p(t)$$

Use numerical integration methods to determine the displacement of the building up to $t = .08$ for the case of

m = 1	
k = 1	
p(t) = 100	0 < t < .04
200	04 < t < .06
-200	06< t

Use the Euler method of integration and an integration time step of $h = .02$.