GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Semester 2004

MECHANICS OF MATERIALS

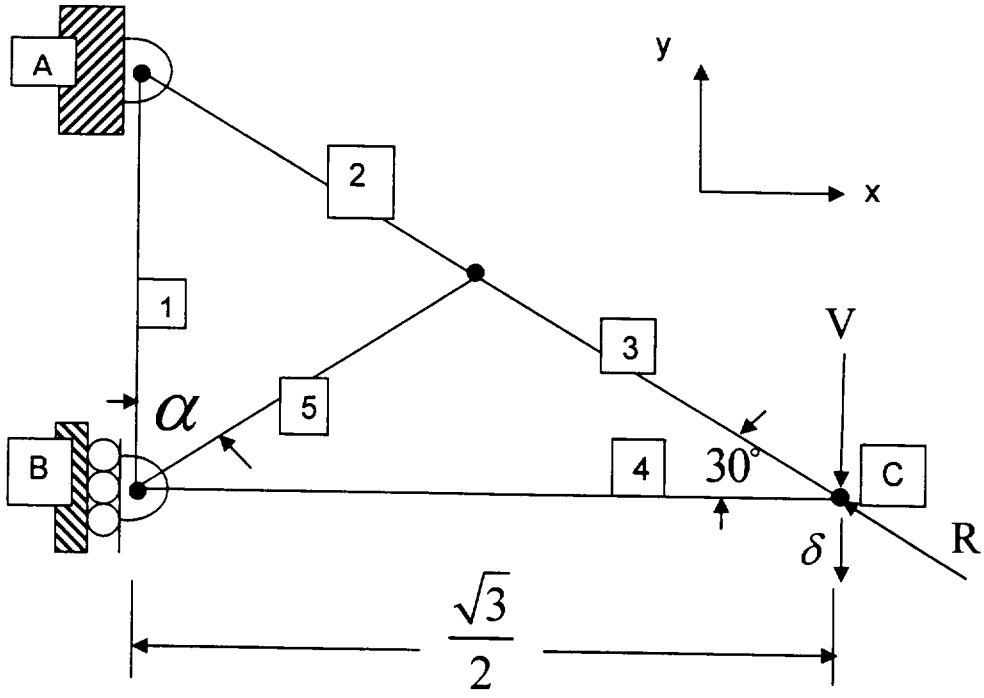
EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

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

Problem 1:

Truss Problem:



The simple pinned joint truss structure shown above has a fixed pinned joint at "A" and a simply supported pin joint (no horizontal displacement) at "B". Vertical displacement δ of the joint at point "C" is affected by applied loads V and R. We limit our consideration to infinitesimal strains in each truss element.

1. Assuming that the material in all truss members or struts to be linear elastic with Young's modulus "E", and that all truss members shown must be present, determine whether there is an angle "α" within the range $0 < \alpha < 90^\circ$ that will minimize the vertical displacement δ at point "C" if only V is applied, with R = 0.

For <u>all</u> the remaining sub-problems, assume $\alpha = 60^\circ$.

2. Determine the cross-sectional areas of the truss members for a minimum-mass truss structure if only force V is applied (R=0) such that the failure stress in all truss elements (assumed equal in tension and compression) would be reached simultaneously.

For <u>all</u> the remaining problems, assume $\alpha = 60^\circ$ and that all truss members have the same diameter (cross sectional area).

3. Given a specified value of V, determine the magnitude of force R, in terms of

V, that produces vertical zero deflection at point "C".

4. If members "2" and "3" obey a power law stress-strain relation of the form $\sigma = K(\varepsilon)^n$, while all other truss elements obey the linear elastic relation $\sigma = E\varepsilon$, derive a V versus δ relation if only force V is applied (R=0).

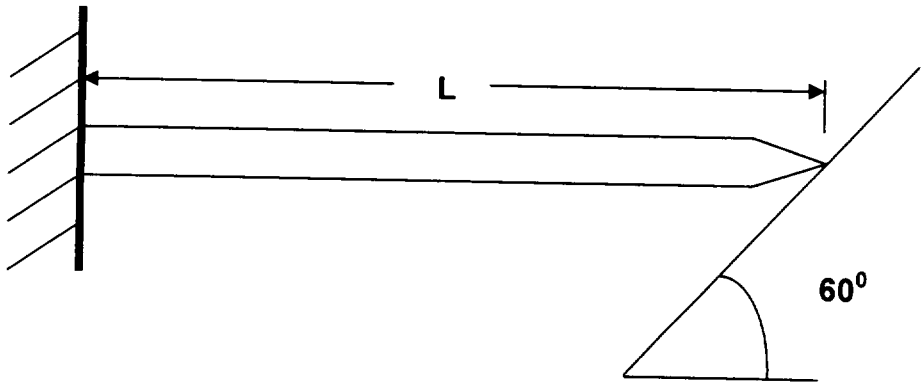
5. Which member is most critical in terms of establishing the buckling resistance of the overall truss structure if only V is applied and all truss members are composed of the same material? Which is most critical if only R is applied in this case? Explain both scenarios.

Problem 2:

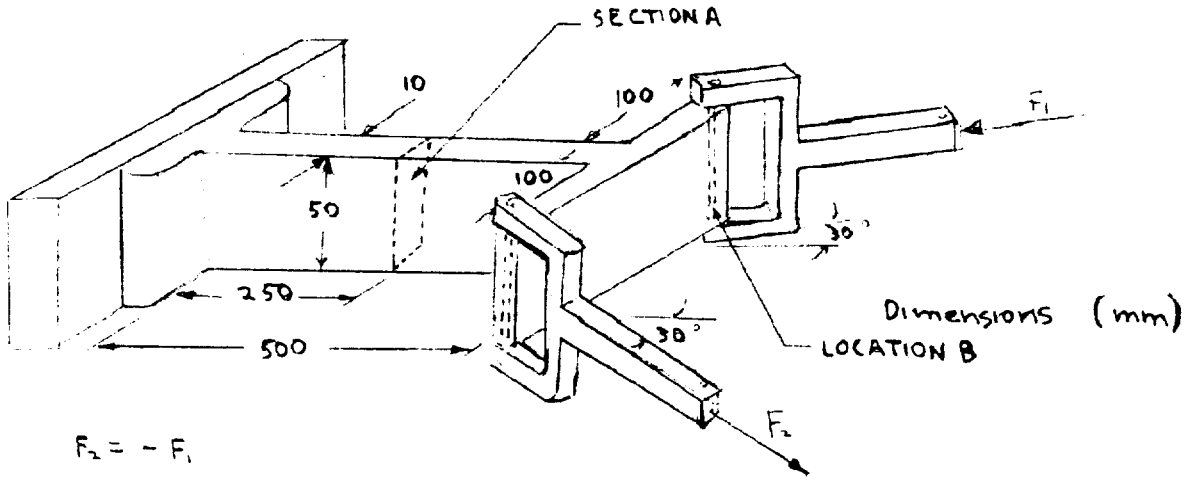
At a given temperature a linear elastic cantilever beam having uniform cross section and properties just rests on the plane as shown. If the temperature of the beam is uniformly raised by ΔT:

- Calculate the maximum deflection of the beam *ignoring* the effect of the axial force on the beam deflection.
- Calculate the maximum deflection of the beam *including* the effect of the axial force on the beam deflection.

You may assume that the plane is frictionless and neglect the weight of the beam. The beam has cross sectional area A, length L, modulus E, area moment I and coefficient of thermal expansion α. The area moment I is for bending about an axis perpendicular to the plan of the drawing.



Problem 3:



$F_2 = -F_1$

Aluminum

$E = 68\ GPa$, $\nu = 0.35$, $\sigma_{ys} = 110\ MPa$

(1). Find the stress distribution at section A in terms of the applied load F_1.

(2). At what load, F_1, will yield occur at section A?

A finite element analysis was performed and the stress at location B was found to be the highest. The stress components at Location B were found to be

$$[\sigma] = \begin{bmatrix} -60 & 30 & 0 \\ 30 & -30 & 0 \\ 0 & 0 & 20 \end{bmatrix}$$

and the octahedral yield criterion in terms of principle stress components is given by

$$\sigma_0 = \frac{1}{\sqrt{2}}\sqrt{(\sigma 1 - \sigma 2)^2 + (\sigma 2 - \sigma 3)^2 + (\sigma 3 - \sigma 1)^2}$$

(3). At Location B, will the material yield based on the octahedral shear stress yield criterion? If not, what is the safety factor against yield?