GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1997

Mechanics of Materials
EXAM AREA

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Assigned Number (DO NOT SIGN YOUR NAME)

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

1. A bi-material beam with a well-bonded, continous interface is shown below. The core material (a) is an elastic-viscous material that creeps according to the law (m > 1)

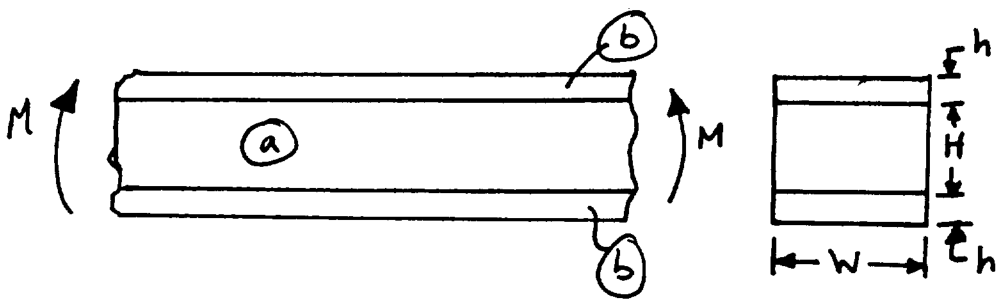
$$\dot{\epsilon}^c = A\sigma^m$$

where A and m are constants and

$$\epsilon = \epsilon^e + \epsilon^c = \frac{\sigma}{E} + \epsilon^c$$

The case material (b) exhibits purely linear elastic behavior

$$\sigma = E\epsilon$$



(i) Qualitatively plot the curvature versus time relation for a section of the beam subjected to a step pure bending moment loading at t = 0. What is the initial curvature?

(ii) Please detail the steps to derive the relaxation of the bending moment with time that occurs if an uniform step curvature is applied at t = 0 to the beam. Plot this behavior. What is the limit as $t \to \infty$ of the moment for a given step of curvature from zero to some value at t = 0?

(iii) If the moment were applied cyclically, would the moment-curvature relation be rate-dependent? If so, what would be the source? If not, why?

(iv) Where does the maximum axial strain occur in the cross section?

(v) Please draw the moment curvature response for very high frequency cyclic loading below.

(vi) What quantities must be continuous across the a - b material interface?

all stress components _____
all strain components _____
displacement _____
strain energy density _____
traction vector _____

Problem #2:

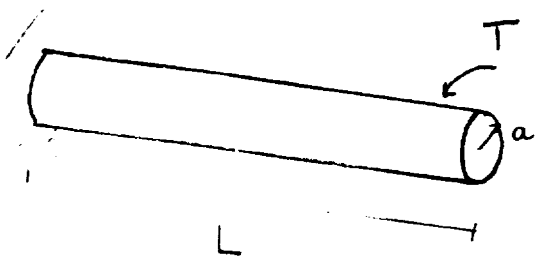
(1) Derive the formula for the effective longitudinal modulus of an unidirectional composite composed of a matrix material and continuous fibers.

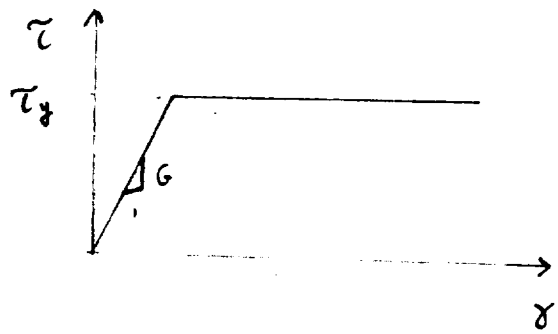
(2) Assume the fiber has an elastic modulus of 400 GPa and an ultimate strength of 4 GPa. The matrix modulus is 20 GPa and behaves linearly until failure at a strain of 0.02. The fiber volume fraction is 0.3. Calculate the maximum longitudinal stress that the composite will sustain before either the fiber or the matrix fails and state which fails first.

Qualifier Problem (Mechanics of Materials) Fall 97

Consider a solid shaft of circular cross-section fixed at one end and loaded with a torque T at the other end. The outer radius is *a* and the length of the shaft is *L*.

1. State the assumptions of strength of materials theory.
2. Derive expressions for stresses and angle of twist in terms of parameters given above.
3. State the location of a maximum stress.
4. If the shaft is made of elastic-perfectly plastic material as shown what is the magnitude of the maximum elastic torque T_y (at the initiation of yielding) and the maximum plastic torque T_p.
5. What will be residual stress distribution after the shaft is unloaded? Sketch.
6. Discuss a Saint-Venant Principle.
7. State boundary conditions for this problem.
8. Explain a sand hill analogy.





4. A weight w = 45 kN is hung eccentrically from the end of a cantilevered pipe of lenght L = 750 mm as shown below. The outer diameter is d = 250 mm, the wall thickness is 6 mm, and a fluid in the pipe has a pressure of 3.5 MPa. Determine the maximum normal and shear stresses at point A. Neglect any stress raiser effects where the pipe is attached.