Ph.D. Qualifying Examination

Mechanics of Materials

Fall 2005

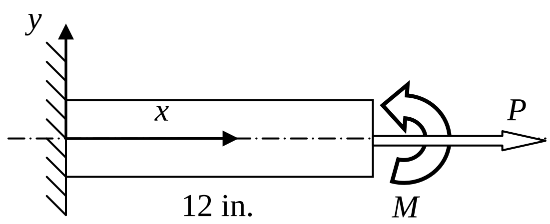
Notes:

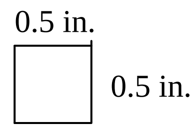
- Time allowed: 2.5 hours.
- Exam is closed book and closed-notes (except for one sheet of “notes”: 8.5$\times$11 in., both sides)
- State your assumptions, methods, and procedures. Show your work on these exam sheets. (Add additional sheets, if needed.)
- You may use a calculator.
- Laptops and cell phones are not allowed.
- Useful information:

  1. Shear modulus of elasticity for carbon steel is 11.5 Mpsi.
  2. Polar area moment of inertia for a round section of radius c is $J = \frac{\pi}{2}c^4$.
  3. Area moment of inertia for a rectangular cross-section is $bh^3/12$.

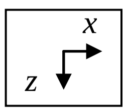
Section One.

The schematic diagram illustrates a load-carrying steel bar. The axial force P at the free end of the member is equal to 3600 lb. The moment load M at the same location is equal to 1800 in.-lb. The length of the bar is 12 in. The bar has a square cross-section of 0.5 in. × 0.5 in.

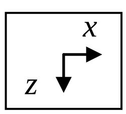




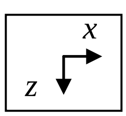
1. Consider a stress element at the top surface of the bar and calculate the bending stress at that surface. Is this stress tensile or compressive? (**circle one**) Show this stress on the stress element provided below.



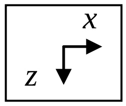
2. Consider a stress element at the bottom surface of the bar and calculate the bending stress at that surface. Is this stress tensile or compressive? (**circle one**) Show this stress on the stress element provided below.



3. Calculate the axial stress in the bar. Show this stress on the stress element provided below.

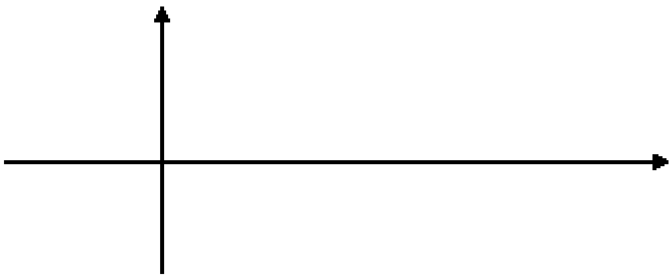


4. Is the top of the bar or bottom of the bar more critical? (**circle one**) Briefly explain your answer. Complete the stress element provided below for the critical part of the bar; i.e., calculate and show the combined stress on the element.



5. Is the stress element you completed in question (4) representing a uni-axial, bi-axial, or tri-axial state of stress (**circle one**).

6. Draw the Mohr's Circle diagram for the stress element of question (4).



7. Use your Mohr's circle diagram to determine the Principal Normal Stresses, in kpsi.

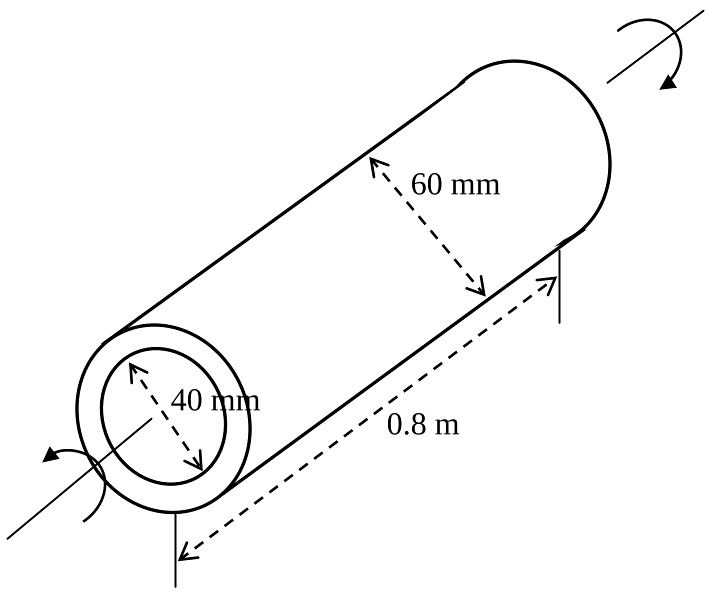
8. Calculate the Maximum Principle Shear Stress:

τ_{max} = ______ kpsi

Section Two.

The preliminary design of a shaft connecting a motor to a generator calls for the use of a hollow shaft with inner and outer diameters of 40 mm and 60 mm, respectively, as shown in the figure below. The maximum allowable shearing stress is 12 MPa. Determine the maximum torque that may be transmitted

(a) by the shaft as designed,
(b) by a solid shaft of the same weight,
(c) by a hollow shaft of the same weight and of 80 mm outer diameter.



Section Three.

For the beam shown using the coordinate system given:

a) Determine the equation for the deflection curve $w(x)$.
b) Sketch the shear, V, and moment, M, diagrams.
c) Find the maximum moment, M_{max} and where it occurs, x_0.

The modulus of elasticity, E, and cross sectional moment of inertia, I, are constant. The length of the beam is L. The peak force per unit length of the triangular loading at $x = L$ is p_0. The beam is fixed at $x = 0$ and simply supported at $x = L$. Write your answers in terms of E, I, L, and p_0