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# E106 Third Examination
# 6 April 2007
# Suggested Exam Time: 75 minutes.
# Long Questions Due in Prof. Spjut's Office
# by Class Time on 7 April 2007

In this examination you may use the class texts and any notes that you have taken in class or made in preparation for the exam. You may also use your homework and quizzes, and my homework solutions. There are two sections to the exam. The first section consists of four short problems, each worth 12 points. They are designed to be answered quickly, without a great deal of derivation or calculation. To pass the class you must get three of the four essentially correct. The second section consists of an eight-part problem with a total value of 52 points. The total possible for the exam is 100 points. The short problems are of equal weight but not of equal difficulty. There is partial credit. Please write neatly and **on one side** of your paper only. You may work on your problems in any order, but please assemble your completed exam with the problems in the correct order and in the correct section. For safety, you may want to write your name on every page.

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# Skill Questions

1. (12 points) A spherical pressure vessel with a maximum pressure of 10 MPa, a radius of 0.5 m, and a yield strength of 350 MPa, must be designed to satisfy the leak-before-break criterion.
   (a) Determine the minimum plane-strain fracture toughness needed.
   (b) Calculate the maximum wall thickness

2. (12 points) A plate undergoing cyclic stress fails after $5 \times 10^5$ cycles. The maximum in the stress cycle is 100 ksi. $A$ is $2.57 \times 10^{-14}$ and $m$ is 4.5 with the stress in ksi and the crack length in inches. The initial crack length was 0.02 inches and the critical crack length was 0.25 inches.
   (a) What was the minimum stress in the stress cycle? Be sure to include units.
   (b) What are the units of $A$?

3. (12 points) An aluminum wire 20 m long and 0.15 mm in diameter has a resistivity at 0 °C of $2.353 \times 10^{-8}$ Ωm. At 35 °C, the wire has a resistance of $30.93\ \Omega$. What is the temperature coefficient of resistivity, $a$, of this aluminum?

4. (12 points) An indium-doped sample of bavarium (a fictitious Group-IV semiconductor) has a conductivity at saturation of 123 $(\Omega\text{m})^{-1}$. The bavarium is doped with $1.0 \times 10^{-7}$ atom-fraction indium. For bavarium $\mu_h = 0.21$ m$^2$/V-s, $\mu_e = 0.45$ m$^2$/V-s, and $A_{\text{Bv}} = 55.905$ g/mol. What is the density of bavarium?

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# Long Question

1. An artist has designed a sculpture which consists of a grossly misshapen head on a tall thin cylindrical column. The head has a mass of 22 kg and needs to be 6 meters above the ground. For maximum artistic effect the column needs to be as thin as possible, and for ease of moving the artwork, the column must be as light as possible. Thin columns fail by buckling, rather than by exceeding the compressive strength, as a squat column might. The load (force) at which a column buckles is given by:

$$F_{\text{crit}} = \frac{\pi^2 EI}{l^2} \tag{1}$$

where $E$ is Young's modulus, $I$ is the second moment of the area, and $l$ is the length (height in this case) of the column. Neglect the weight of the column in your load calculations.

   (a) (6 points) List the function(s) of the column.

   (b) (6 points) List the constraint(s).

   (c) (6 points) List the objective(s).

   (d) (6 points) List the design equations.

   (e) (6 points) Determine the Performance Indices (or their reciprocals) for the column.

   (f) (6 points) Calculate the mass of the column for all four materials below.

   (g) (6 points) Calculate the radius of the column for all four materials below.

   (h) (10 points) Rank the materials on the table below from best to worst for the artist's application.

| Material | Density ($kg/m^3$) | Youngs modulus (GPa) | Yield strength (MPa) |
|---|---|---|---|
| High Modulus CFRP | 1700 | 220 | 760 |
| 4340 Steel | 7850 | 207 | 1620 |
| Sintered SiN | 3300 | 304 | 650 |
| Douglas Fir | 500 | 13.6 | 108 |