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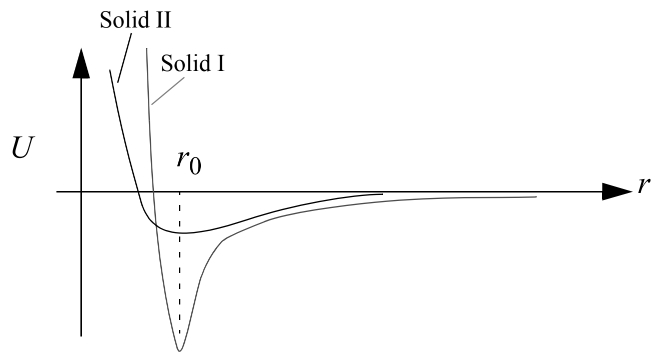
Your Name Goes On This Line

E98 Final Examination
14 December 1999
Exam Time: 180 minutes.

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 exams, and our homework and exam solutions. *All other references are forbidden*. There are two sections to the exam. The first section consists of nine short problems, each worth 10 points. They are designed to be answered quickly, without a great deal of derivation or calculation. The second section consists of three problems, each worth 30 points. The total possible for the exam is 180 points. Within each section, the 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.

Section I – Short Questions (10 Points Each)

1. The potential energy curves for two solids are shown below:



   Rank the two solids in terms of their expected melting temperatures, strength, modulus of elasticity, and thermal expansion coefficient. Explain your reasoning.

2. Calculate the ratio of the densities of chromium and aluminum from atomic weights and microstructures and compare it with the literature value of 2.653 at 20°C.

3. In what crystallographic direction is the line of intersection between the $(1\bar{1}0)$ and the $(1\bar{1}\bar{2})$ planes:
   a. in a cubic structure?
   b. in a tetragonal structure?

4. An iron oxide contains 52 atomic percent oxygen. What is the Fe^{2+}/Fe^{3+} ion ratio?

5. Determine the amount of pearlite in 100 g of a 99.5 weight percent Fe – 0.5 weight percent C alloy that is air cooled from 870°C.

6. A 200 cm long copper wire (with an elastic modulus of 110 GPa) is loaded in tension with a 250 MPa stress to produce a strain of 0.01. What is the length of the wire when the load is removed?

7. A copper pipe creeps at a steady-state rate of 0.002 $(\text{hour})^{-1}$ when a stress of 100 MPa is applied at 600°C. Assuming the steady-state creep rate of copper is due to self diffusion of copper atoms, estimate the steady-state creep rate at 800°C. The activation energy for self-diffusion in copper is 211 kJ/mol.

8. 0.104 moles of hydrogen peroxide are added to 76.02 moles of vinyl acetate. Estimate the number-averaged degree of polymerization of the product.

9. Stoichiometric GaAs has a number density of 2.215×10^{28} Ga atoms/m^3 at room temperature. Calculate the electrical conductivity of $Ga_{1+\delta}As$ at room temperature for $\delta = 0.000001$. Table 19.2 on p.617 of Callister may help.

Section II – Long Questions (30 Points Each)

1. In order to test the strength of a ceramic, cylindrical specimens of length 25 mm and diameter 5 mm are tested in a three-point bending apparatus. Half of the specimens broke for applied loads of 300 N and less. The test is to be repeated using specimens of length 50 mm and diameter 10 mm. Estimate the applied load that will give a probability of failure of 10^{-6}. Assume the Weibull modulus of the ceramic, $m = 10$. The survival probability is:

$$\phi = \exp\left\{\frac{-v}{v_0}\left(\frac{\sigma}{\sigma_0}\right)^m\right\} .$$

2. A sheet of aramid-fiber reinforced epoxy is rigidly clamped at 25°C along its edges parallel to and perpendicular to the fiber direction. To what temperature can the sheet be cooled before the thermal stress transverse to the fibers exceeds the tensile strength transverse to the fibers? Elastic moduli, tensile strengths, and coefficients of thermal expansion are given in Appendix B, Tables B.2, B.4, and B.6 of Callister. Assume a value of Poisson's ratio of $\nu_{lt} = 0.34$ for longitudinal loading.

3. Pressure vessels are sometimes protected from catastrophic failure with a rupture disc, a thin circular disk of radius r and thickness t that is designed to fail or rupture at a given pressure. Often the discs are scored with a thin groove of depth a to provide a rupture point. The maximum deflection δ, and maximum tensile stress σ, in a disk subject to pressure p, are reasonably approximated by:

$$\delta = \frac{2r^4p}{3Et^3} \text{ , and } \sigma = \frac{5r^2p}{4t^2} .$$

For a fixed radius, groove depth, and pressure, which steel, 1040, or 4340 tempered at 425°C, would make the least expensive rupture disk?