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Your Name Goes On This Line

E106 Final Examination
13 December 2000
Suggested Exam Time: 3 hours.
Due in Prof. Spjut's office
by 2 PM on 14 December 2000

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. *All other references are forbidden*. There are two sections to the exam. The first section consists of eight 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 six of the eight essentially correct. The second section consists of four problems, each worth 26 points. The total possible for the exam is 200 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 – Skills Questions (12 Points Each)

1. Calculate the fraction of lattice sites that are vacant in a material with an energy of vacancy formation of 1.25 eV at 1453 K.

2. A $1\ \text{cm} \times 1\ \text{cm} \times 1\ \text{cm}$ cube has a tensile force of 800 N applied along the *x*-direction, a tensile force of 300 N applied along the *y*-direction and a compressive force of 500 N applied along the *z*-direction. Determine the stress vector for this cube

3. A spherical pressure vessel is subjected to a periodic pressure of 800 kPa. The vessel radius is 1.5 m, and the material has a yield strength of 120 MPa. To ensure leak-before-break conditions, what is the minimum fracture toughness of the vessel? What should the wall thickness be?

4. What is the expected coordination number for Ti^{4+} ions in TiI_4?

5. At what load will a cylindrical soda-lime glass sample break? Conditions: $\sigma_f = 69\ \text{MPa}$, $L = 33\ \text{cm}$, $r = 3\ \text{mm}$, simply supported ends, concentrated load in center.

6. What length of 0.2 mm diameter Nickel 200 wire (properties on p.813 of Callister) is needed to create a 1234 ¾ wirewound resistor?

7. Germanium ($A_{Ge} = 72.59\ \text{g/mol}$, $\rho = 5.32\ \text{g/cm}^3$, $\mu_e = 0.38\ \text{m}^2\text{/V-s}$, $\mu_h = 0.18\ \text{m}^2\text{/V-s}$) is doped with arsenic. Calculate the atomic fraction of arsenic if the conductivity of the doped germanium is $2718\ (¾\ \text{m})^{-1}$.

8. A flat-plate capacitor with dimensions $2\ \text{m} \times 0.5\ \text{m}$ has a plate separation of 1 mm. The dielectric constant of the material between the plates is 4.8. Calculate the capacitance of the capacitor.

Section II – Long Questions (26 Points Each)

1. 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 along a diameter 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:

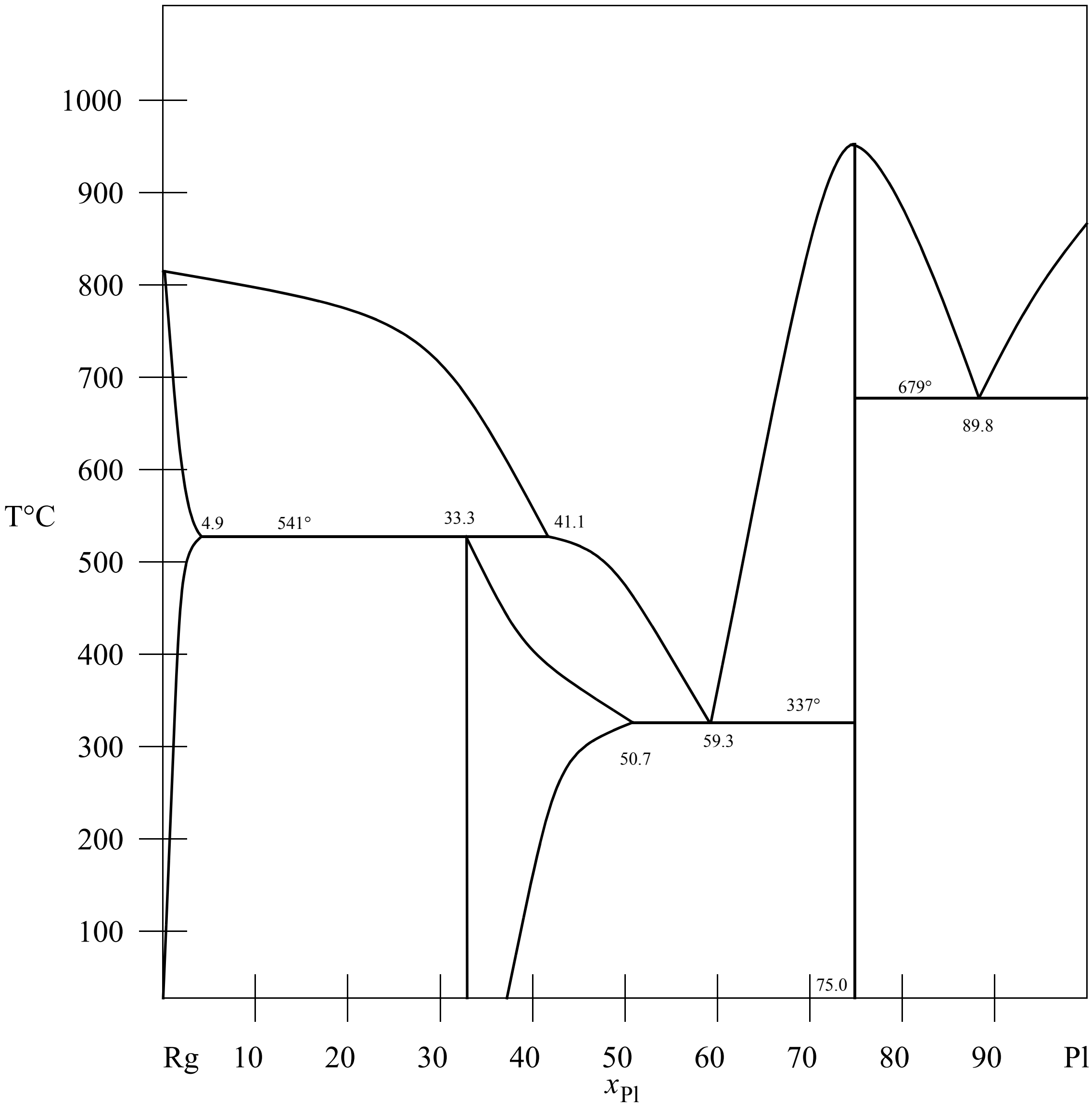
$$\delta = \frac{2r^4p}{3Et^3}\ \text{, and}\quad \sigma = \frac{5r^2p}{4t^2}\ .$$

For a fixed radius r, groove depth a, and pressure p, which steel, 17-7PH, or 4340 tempered at 425°C, would make the least expensive rupture disk?

2. An aluminum-doped silicon sample is an extrinsic semiconductor with a conductivity of 1200(¾m)$^{-1}$. In order to create a diode, the sample is heated to 1600°C and held for 2 hours. While at temperature, one surface of the sample is exposed to a gaseous mixture that maintains the surface concentration of Al at its bulk value and causes a surface concentration of phosphorus of 2.878×10^{23} atoms/m^3. The sample is then cooled. Assume that the diffusivity of phosphorus in silicon is the same as that of boron in silicon given in Problem 19.D5 on p.657 of Callister.
   a) What is the room-temperature conductivity of the exposed surface?
   b) At what depth (in μm) is the p-n junction?

3. An initially $1\ \text{cm} \times 1\ \text{cm} \times 1\ \text{cm}$ cubic sample of an aramid composite (properties in Table 17.5 on p 542 of Callister, assume $\nu_{lt} = 0.2$) has continuous fibers aligned in the *x*-direction. A tensile force of 800 N is applied along the *x*-direction. A tensile force of 300 N is applied along the *y*-direction. A compressive force of 500 N is applied along the *z*-direction. Calculate the change, (Δl's), in the dimensions of the cube.

4. The plattium-regurgium phase diagram is shown on the next page. Composition is in atomic percent.
   a. Label all of the one-phase regions. The Rg-rich phase is α, the Pl-rich phase is δ, the incongruently-melting phase is β, and the congruently-melting intermetallic is γ.
   b. Label all of the two phase regions, *e.g.*, $l+\alpha$.
   c. Write down all three-phase invariant reactions with the temperatures at which they occur, *e.g.*, $\alpha + \beta \rightarrow \gamma$ at 1124°C.
   d. For a 10 atomic-percent Pl mixture which has been cooled from 1000°C to 300 °C list the *phases* present at 300°C and calculate their relative amounts.
   e. For a 68 atomic-percent Pl mixture which has been cooled from 1000°C to 336 °C list the *microconstituents* present at 336°C and calculate their relative amounts.
   f. What is the chemical formula for the congruently-melting intermetallic?


1000
900
800
700
600
500
400
300
200
100
T°C
4.9
541°
33.3
41.1
337°
59.3
50.7
679°
89.8
75.0
Rg
10
20
30
40
50
60
70
80
90
Pl
x_{Pl}