

Exam is closed book, closed notes, closed neighbors

Instruction:

1. Write your name and student ID on top of page.
2. Write legibly.
3. Show work as needed to justify answers
4. Underline all final numerical answers
5. You are provided with a periodic table with electronegativities listed, and an equation sheet (values for constants are on the equation sheet)

Problem 1 (10 points):

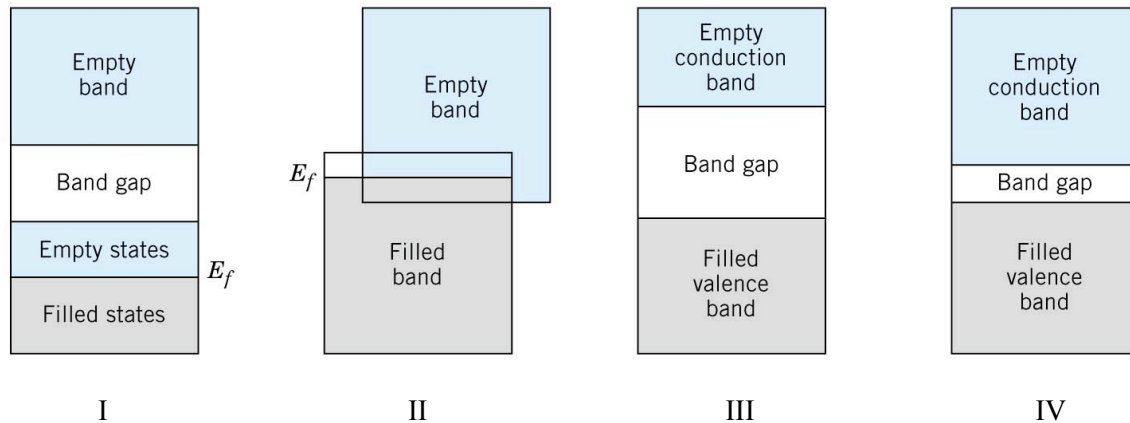
Mark **True (T)** or **False (F)** for the following statements.

1. Metallic bonding is the strongest type of bonding out of the primary bonds.
2. fcc is a close-packed structure.
3. Silicon will diffuse faster than carbon through a sheet of iron.
4. The Burgers vector for an edge dislocation is perpendicular to the dislocation line.
5. Engineering stress of a material is greater than its true stress.
6. The electrical conductivity of all materials increases with temperature.
7. In general, the fracture toughness of a ceramic is greater than that of a metal.
8. The rate of isothermal transformation of steel from austenite (γ) to pearlite (α ferrite + Fe_3C cementite) increases with increasing temperature.
9. Aluminum becomes harder during recrystallization.
10. The rate of corrosion decreases with temperature.

Problem 2 (16 points):

Multiple choice questions. There is only one correct answer for each question.

1.



From the figure above, what type of electron band structure would you predict for 50 atom% sodium and 50 atom% fluorine?

- A I
- B II
- C III
- D IV
- E I or II

2. From the figure above, what type of electron band structure would you predict for 50 atom% iron and 50 atom% copper?

- A I
- B II
- C III
- D IV
- E I or II

3. From the figure above, what type of electron band structure would you predict for 50 atom% silicon and 50 atom% carbon?

- A I
- B II
- C III
- D IV
- E I or II

4. The mobility of electrons above the Fermi Energy, E_F :

- A increases with temperature due to increase thermal motion
- B are close to the speed of light because the electrons are in the bandgap
- C increases with cold work because they move faster on dislocation highways
- D decreases with temperature due to increased thermal motion
- E is less than that of holes because holes have no mass

5. As the molecular weight of a semicrystalline polymer is increased, how will this change the degree of crystallinity?

- A Decrease, because the chains are more likely to get tangled up
- B Increase, because it is more thermodynamically favorable with larger chains
- C Not known because crystallinity depends only on the monomer unit shape
- D Not known since the degree of crystallinity is dependent on carbon content.

6. In a thermoplastic polymer, adjacent polymer chains are bonded by:

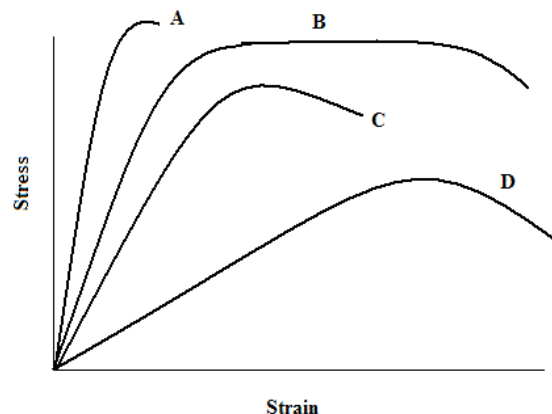
- A covalent bonds
- B primary bonds
- C ionic bonds
- D secondary bonds
- E nothing

7. Above the glass transition temperature, polymers are:

- A brittle, because the chains have crosslinked
- B viscous, because of molecular motion
- C rubbery, because of molecular motion
- D transparent, because of the molecular motion
- E crystalline, because the chains can fold back on themselves

8. Which of the four stress-strain curves to the right show the greatest tensile strength?

- A
- B
- C
- D
- E not enough information on the diagram to tell

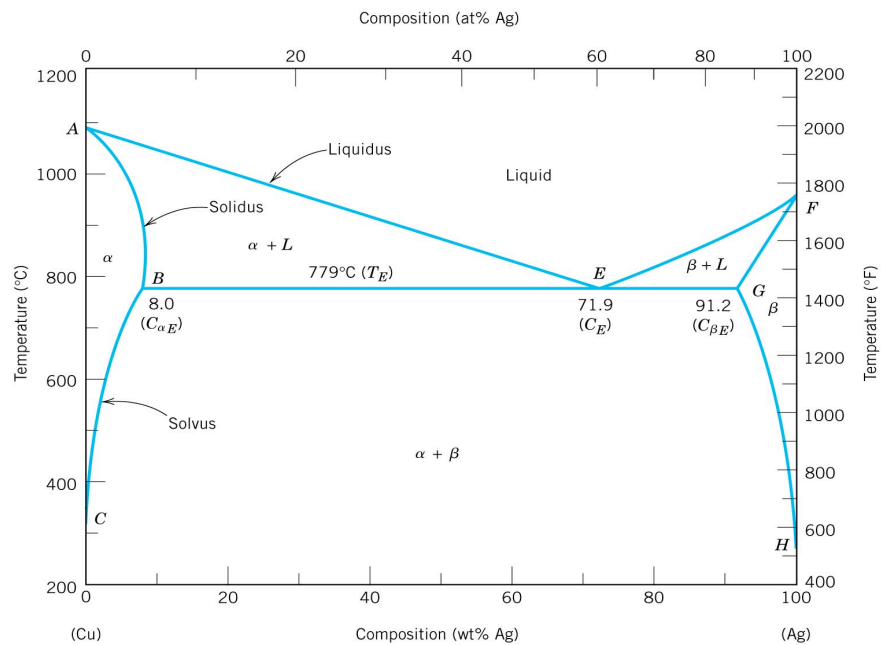
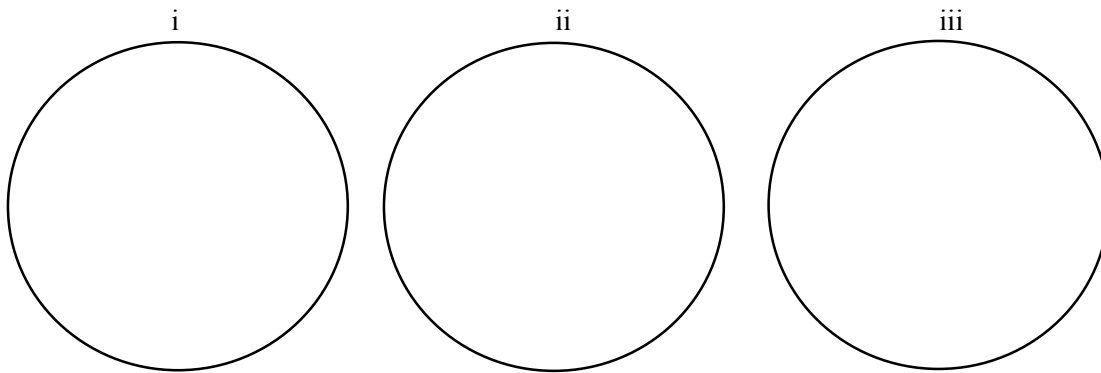


Problem 3 (20 points):

The Cu-Ag phase diagram for this question is shown below.

A. Sketch the microstructure that would form if the following compositions were slowly cooled from liquid to 50 °C.

- (i) 95wt% Cu
- (ii) 85wt% Ag
- (iii) 71.9wt% Ag



B. The alloys in this part of the question refer to part 3A on the previous page. What is the composition of:

(i) solid in alloy A(ii) at 779.1 °C

(ii) liquid in alloy A(ii) at 779.1 °C

(iii) solid in alloy A(i) at 779.1 °C.

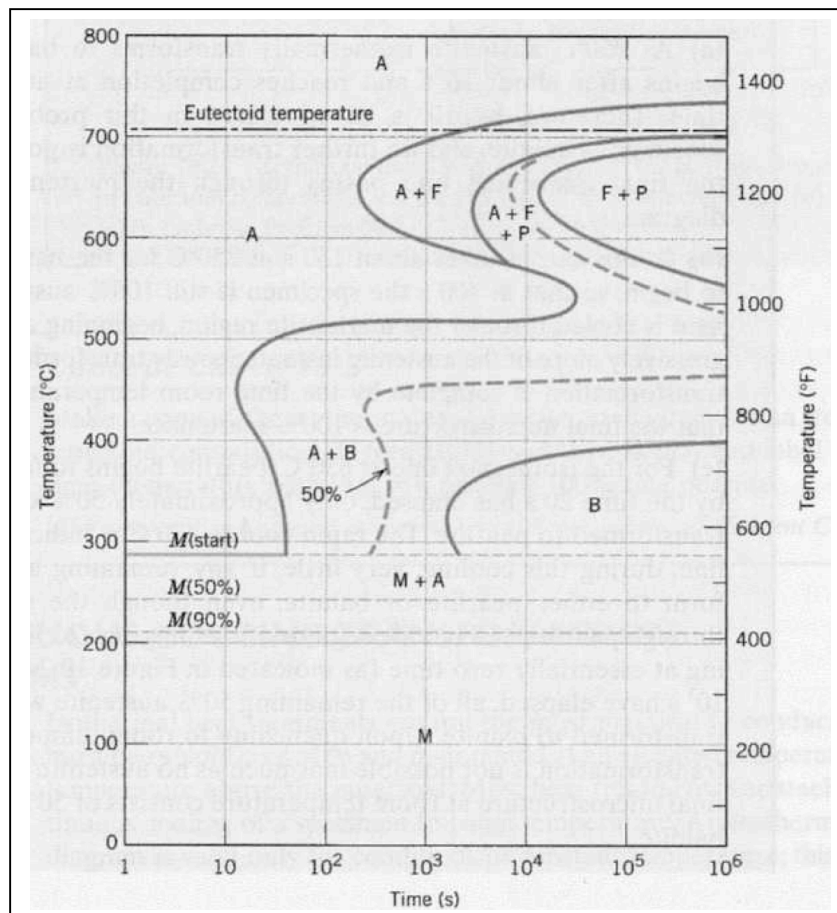
C. If you heat alloy A(i) from room temperature, at what temperature would melting (formation of liquid phase) start?

D. What weight fraction of liquid is present in alloy A(ii) at 779.1 °C.

Problem 4 (20 points):

Based on the following heat treatments and the given transformation diagram for a steel, determine what phases and amount of each phase are present, starting from 800 °C.

- (i) Quickly cool to 240 °C, hold for 100 s, then *slow* cool to 25 °C.
- (ii) Quickly cool to 400 °C, hold for 6 min, then *slow* cool to 25 °C.
- (iii) Quickly cool to 25 °C, then reheat to 250 °C for 1 hour.
- (iv) Quickly cool to 600 °C, hold for 1000 s, then quench to 25 °C.



Problem 5 (20 points):

- A. Describe what Schottky and Frenkel defects are. Also, explain in which class of materials they occur and why.
- B. Would you expect Frenkel defects for anions to exist in ionic ceramics in relatively large concentrations? Why or why not?
- C. What point defects are possible for MgO as an impurity in Al_2O_3 ? How many Mg^{2+} ions must be added to form each of these defects?

Problem 6 (20 points):

Briefly explain how each of the following influences the tensile or yield strength of a semicrystalline polymer and why:

A. Molecular weight

B. Degree of crystallinity

C. Deformation by drawing (drawing is when the polymer is deformed while under tension ie. stretched).

D. Annealing (heating polymer below its melting temperature and cooling to room temperature) of an undeformed material.

E. During the winter months, the temperature in some parts of Alaska may go as low as -55 °C. Of the elastomers, natural isoprene, styrene-butadiene, acrylonitrile-butadiene, chloroprene, and polysiloxane, which polymers would be suitable for automobile tires under these conditions? Which polymers would be suitable for Seattle?

	Elongation (%)	Useful temperature range (°C)
Natural isoprene	500-760	-60 - 120
Styrene-butadiene	450-500	-60 - 120
Acrylonitrile-butadiene	400-600	-50 - 150
Chloroprene	100-800	-50 - 105
Polysiloxane	100-800	-115 - 315

Problem 7 (20 points)

- A. Name two advantages a fiber strengthened polymer matrix composite has compared to a polymer on its own.
- B. Sketch a plot of the elastic modulus vs. volume fraction of fibers in the longitudinal direction and the transverse direction for a unidirectional carbon fiber epoxy composite. The properties of the carbon fiber and epoxy are shown below. You do not have to calculate every data point on the curves, but you need to have the values for the maximum and minimum values for elastic modulus.

Property	Carbon fiber	Epoxy
Strength	4 GPa	20 MPa
Failure strain (%)	0.1 %	5%
Elastic Modulus	500 GPa	5 GPa

Problem 8 (20 points):

- A Explain why metals are conductive. Draw band structure(s) to help with your explanation.
- B An aluminum wire 10 m long must experience a voltage drop of less than 1.0 V when a current of 5 A passes through it. Given that the electrical conductivity of aluminum is $3.8 \times 10^7 (\Omega\text{m})^{-1}$, calculate the minimum diameter of the wire.
- C If a metallic material is cooled through its melting temperature at an extremely rapid rate, it will form a noncrystalline solid (ie. a metallic glass). Will the electrical conductivity of the noncrystalline material be greater or less than its crystalline counterpart? Why?

- D The following electrical characteristics have been determined for both intrinsic and p-type extrinsic gallium antimonide (GaSb) at room temperature. Calculate the electron and hole mobilities. (*This comment may confuse some people, but note that n and p are similar for this extrinsic case, so be careful about simplifying the equation.*)

	$\sigma((\Omega\text{m})^{-1})$	$n(\text{m}^{-3})$	$p(\text{m}^{-3})$
Intrinsic	8.9×10^4	8.7×10^{23}	8.7×10^{23}
Extrinsic (p-type)	2.3×10^5	7.6×10^{22}	1.0×10^{25}

Problem 9 (20 points)

- A. Corrosion is defined as the destructive and unintentional attack of a metal, and it is an electrochemical reaction. Would you expect iron to corrode in water of high purity? Why or why not?
- B. Suggest an appropriate class of materials for each of the following applications, and, if necessary, recommend corrosion prevention measures that should be taken. Justify your answer.
- (i) Laboratory bottles to contain relatively dilute solutions of nitric acid.
 - (ii) Barrel to contain benzene.
 - (iii) Pipe to transport *hot* alkaline (basic) solutions.
 - (iv) Underground tanks to store large quantities of high-purity water.

$$\%ionic = \left\{ 1 - e^{-0.25(X_A - X_B)^2} \right\} \times 100$$

$$N_v = Ne^{\left(-\frac{Q_v}{kT}\right)}$$

$$J = -D \frac{dC}{dx}$$

$$\nu = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\varepsilon_y}{\varepsilon_z}$$

$$\tau_R = \sigma \cos \lambda \cos \phi$$

$$\sigma_m = 2\sigma_0 \left(\frac{a}{\rho_t} \right)^{1/2}$$

$$K_c = Y\sigma_c \sqrt{\pi a}$$

$$M_w = \sum w_i M_i$$

$$\frac{1}{E_{ct}} = \frac{V_m}{E_m} + \frac{V_f}{E_f}$$

$$\sigma = n|e|\mu_e + p|e|\mu_h$$

$$N_A = 6.022 \times 10^{23} \text{ atoms/mol}$$

$$R = 8.314 \text{ J/molK}$$

$$F = 96,500 \text{ C/mol}$$

$$N = \frac{N_A \rho}{AW}$$

$$J = \frac{M}{At}$$

$$D = D_0 e^{\left(-\frac{Q_d}{RT}\right)}$$

$$\%EL = \left(\frac{l_f - l_0}{l_0} \right) \times 100$$

$$\%CW = \left(\frac{A_f - A_0}{A_0} \right) \times 100$$

$$\sigma_c = \left(\frac{2E\gamma_s}{\pi a} \right)^{1/2}$$

$$M_n = \sum x_i M_i$$

$$E_{cl} = E_m V_m + E_f V_f$$

$$\Delta V = \left(V_2^0 - V_1^0 \right) - \frac{RT}{nF} \ln \left[\frac{M_1^{n+}}{M_2^{n+}} \right]$$

$$\rho = \frac{1}{\sigma} = \frac{VA}{Il}$$

$$k = 1.38 \times 10^{-23} \text{ m}^2\text{kg s}^{-2}\text{K}^{-1}$$

$$= 8.62 \times 10^{-5} \text{ eV/K}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

