ENGR/MSE 170 Midterm 03/20/08 166pts. total

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. Potassium iodide (KI) has predominantly ionic bonding.

2. Polycrystalline materials exhibit anisotropic mechanical properties.

3. Surface energy of single crystal increases with planar density.

4. The rate of diffusion is faster for interstitial diffusion than it is for vacancy diffusion.

5. Engineering stress of a material is greater than its true stress.

6. Increasing the amount of impurities in a material will increase its ductility.

7. Crack propagation occurs when the maximum stress, σ_m, at the crack tip is greater than the critical stress, σ_c.

8. The rate of isothermal transformation of steel from austenite (γ) to pearlite (α ferrite + Fe_3C cementite) increases with increasing temperature.

9. During precipitation hardening, the hardness of a material increases with overaging.

10. A Frenkel defect involves a cation vacancy and a cation interstitial pair.

Problem 2 (16 points):

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

1. What are the two characteristics of the component ions that determine the crystal structure of a ceramic?

A Color and charge
B Ionic radius and charge
C Atomic radius and electronegativity
D Ionic radius and atomic radius
E Band gap and diffusion coefficients

2. Fiber-reinforced polymer matrix composites improve the properties of polymers by:

A increasing the fracture toughness and ductility
B increasing the strength and modulus
C decreasing the strength to weight ratio
D all of the above
E none of the above

3. Increasing the molecular weight of a polymer:

A increases the elastic modulus of the polymer
B increases the ductility of the polymer
C increases the T_g of the polymer
D none of the above
E A and C
F B and C

4. A single phase, α brass alloy has been 30% cold worked, heated to 0.5 T_m for 30 minutes, and then quenched. The expected mechanical properties are:

A hard and brittle metal because it formed martensite
B approximately the same ductility as before cold working because of recrystallization
C increased tensile strength because of precipitation hardening
D approximately the same hardness as before cold working because of recovery
E all of the above

5. When Al atoms are doped into pure Si, the material becomes:

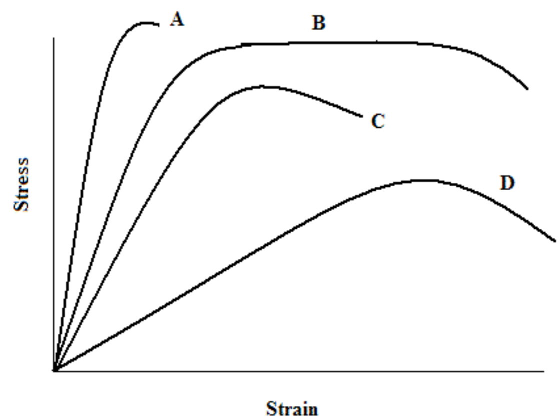
A p-type
B n-type
C intrinsic
D metallic

6. When the temperature is raised, electrical conductivity of pure Al will be:

A unchanged
B increased
C decreased
D infinite

7. Which of the four stress-strain curves to the right show the highest toughness?

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



8. Stainless steel has 0.5 wt% C and 11 wt% Cr in a Fe matrix. The diffusion coefficient of C in the alloy is:

A equal to that of Cr
B greater than that of Cr because of the lower concentration
C greater than that of Cr because it is the smaller atomic species
D none of the above

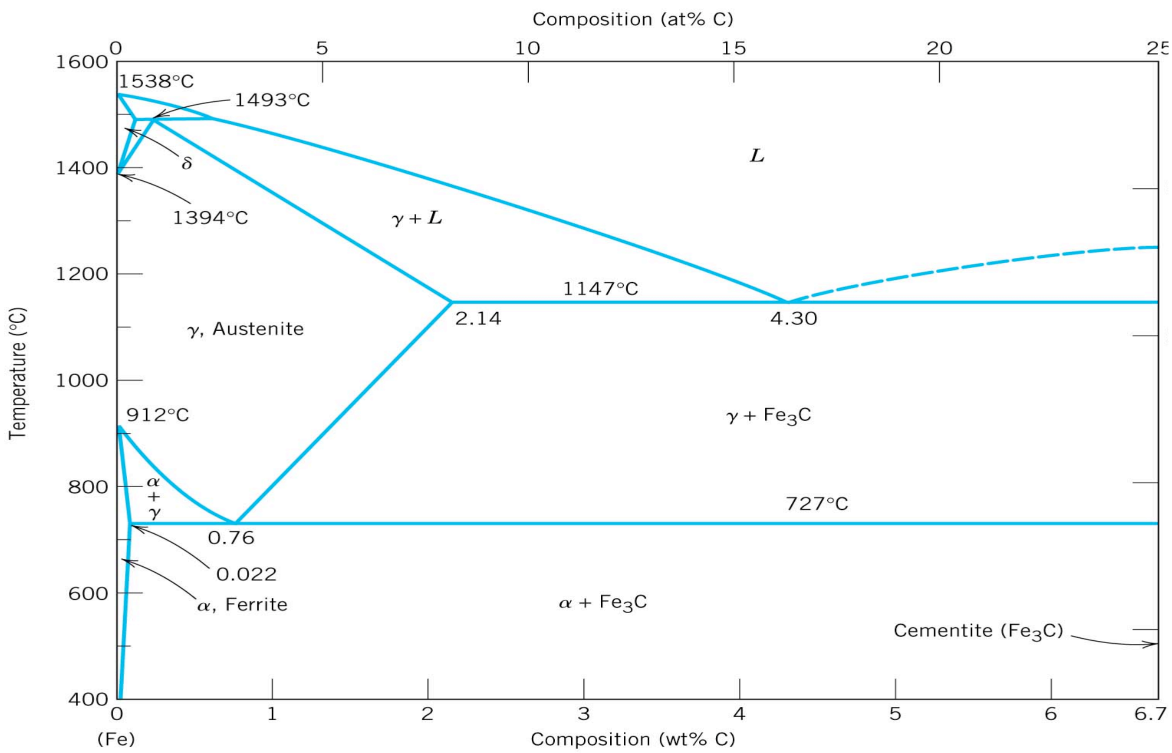
Problem 3 (20 points):

The phase diagram for this question is on page 5. For a slowly cooled carbon steel alloy with 0.4 wt% carbon:

A. What weight fraction of total ferrite, α, would be present at 700 °C.

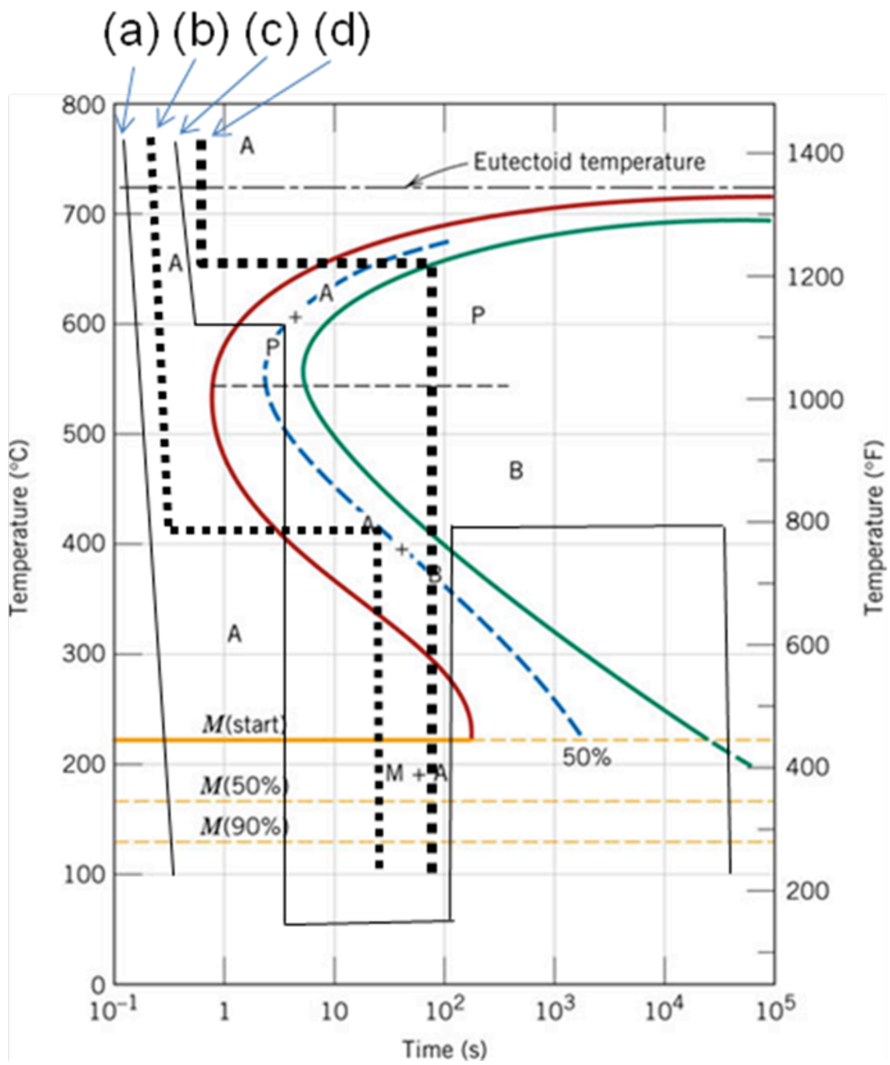
B. What weight fraction of pearlite (eutectoid $\alpha + Fe_3C$) is present at 700 °C.

C. Starting with a ferrite + pearlite microstructure, what temperature would you need to **heat** the steel to before quenching, if you wanted to create a 100% martensitic microstructure?



Problem 4 (20 points):

Given below is an isothermal transformation diagram for hypoeutectoid Fe-Fe_3C with four time-temperature paths illustrated. Identify the percentage of each microstructure present at termination of each path. For the microstructures, write down their names (ie. bainite, pearlite. etc.) instead of the letters shown in the diagram below.



Path (a):

Path (b):

Path (c):

Path (d):

Problem 5 (20 points):

A customer needs a material that has a very high modulus and can operate in a high temperature, corrosive environment.

A. What class of material (metal, ceramic, or polymer) would you choose for this application?

B. Why does this class of materials have the desired properties?

C. What disadvantages might this type of material have?

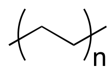
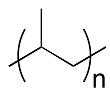
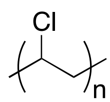
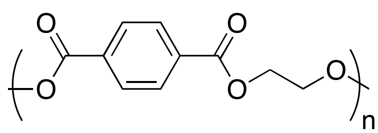
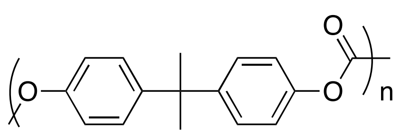
D. If the part must be able to carry a tensile stress of 100 MPa and your quality control team can only detect flaws (eg. cracks) bigger than 0.5 mm, what fracture toughness must your materials have? Assume Y = 1.2.

Problem 6 (20 points):

A. Explain what the glass transition temperature of a polymer is.

B. What are the major differences between a thermoset polymer and a thermoplastic polymer? Which class of polymers will have the higher T_g?

C. Using the table on the following page, describe the trend in the T_g and T_m of the polymers. Be specific about how substituents and polymer backbone structure affect the two temperatures.

Materials	T_g (°C)	T_m (°C)
Polyethylene 	-110	115
Polypropylene 	-18	175
Poly(vinyl chloride) 	87	212
Polyester (PET) 	69	265
Polycarbonate 	150	265

D. In the table above, which polymer(s) would be best suited for use as ice cube trays? Why?

Problem 7 (20 points)

A continuous and aligned fibrous reinforced composite having a cross-sectional area of 970 mm^2 is subjected to an external tensile load. If the stresses sustained by the *fiber* and *matrix* phases are 215 MPa and 5.38 MPa, respectively, the force sustained by the *fiber* phase is 76,800 N, and the total longitudinal *composite* strain is 1.56×10^{-3}, then determine:

A. the force sustained by the *matrix* phase.

Hint: you need to calculate the cross-sectional area of the matrix, which can be found once you have calculated the total cross-sectional area of the fibers.

B. the modulus of elasticity of the *composite* material in the longitudinal direction? Hint: you will need to consider the total force the composite is experiencing.

C. the moduli of elasticity for *fiber* and *matrix* phases.

Note: fiber strain = matrix strain = composite strain

Problem 8 (20 points):

Calculate the electrical conductivity of Materials A, B, and C.

Si: electron mobility = 0.14 m^2/Vs, hole mobility = 0.05 m^2/Vs.

Material A: Silicon doped with phosphorous to give a concentration of 10^{23} m^{-3} charge carriers.

Material B: Silicon doped with boron to give a concentration of 10^{24} m^{-3} charge carriers.

Material C: Pure silicon with a concentration of 10^{16} m^{-3} charge carriers.

Problem 9 (20 points)

A. Briefly explain the difference between oxidation and reduction electrochemical reactions.

B. Tin cans are made of steel which is coated with a thin layer of tin. Tin protects the steel from corrosion by food products although it is electrochemically less active than steel in the galvanic series. Explain. *This is a trick question…*

C. An Fe/Fe^{2+} concentration cell is constructed in which both electrodes are pure iron. The Fe^{2+} concentration for one cell half is 0.5 M, for the other, 2×10^{-2} M. Is a voltage generated between the two cell halves? If so, what is its magnitude and which electrode will be oxidized? If no voltage is produced, explain this result. The standard electrode potential for Fe^{2+} is -0.44 V.

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

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

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

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

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

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

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

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

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

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

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

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

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

$$M_n = \sum x_i M_i$$

$$M_w = \sum w_i M_i$$

$$E_c = E_m V_m + E_p V_p$$

$$\frac{1}{E_c} = \frac{V_m}{E_m} + \frac{V_p}{E_p}$$

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

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

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

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

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

R = 8.314 J/molK

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

F = 96,500 C/mol

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
H 2.1																	He –
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne –
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar –
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8	Kr –
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5	Xe –
Cs 0.7	Ba 0.9	La–Lu 1.1–1.2	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2	Rn –
Fr 0.7	Ra 0.9	Ac–No 1.1–1.7															

← Give up electrons

Acquire electrons →