ENGR/MSE 170 **Midterm 02/17/10** **100pts. total**

Exam is closed book, closed neighbors, one side of notes allowed

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, a coordination number table, 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. The electron configuration of Ni^{2+} is $1s^2 2s^2 2p^6 3s^2 3d^7 4s^1$. F

2. Covalently bonded materials typically are less dense than metallically or ionically bonded materials because the covalent bonds are directional, thereby restricting the atomic packing factor. T

3. Polycrystalline materials exhibit anisotropic mechanical properties. F

4. [100] is perpendicular to (100) in a cubic crystal. T

5. The surface energy of a single crystal decreases with planar density. F

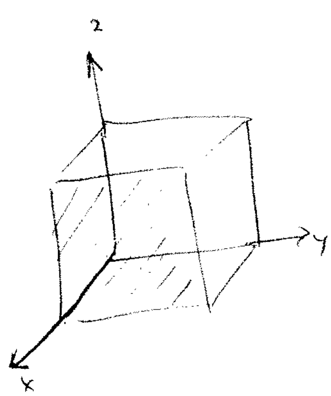
6. The rate of diffusion of carbon through steel increases with temperature. T

7. Materials A and B withstand a strain of 0.23 and 0.40 respectively at the point of fracture. This means that material A will experience a greater percent reduction in area compared to B. F

8. Material A has a yield strength of 310 MPa and an elastic modulus of 210 GPa. Material B has a yield strength of 700 MPa and an elastic modulus of 210 GPa. This means that Material A is stiffer than Material B. F

9. When annealing a metal, its ductility increases during grain growth. F

10. If a materials shows a ductile-to-brittle transition, that means that the material shows ductile behavior at temperatures below the transition temperature. F



Problem 2 (18 points):

A) Potassium iodide (KI) exhibits predominantly ionic bonding. The K^+ and I^- ions have electron structures that are identical to which two inert gases.

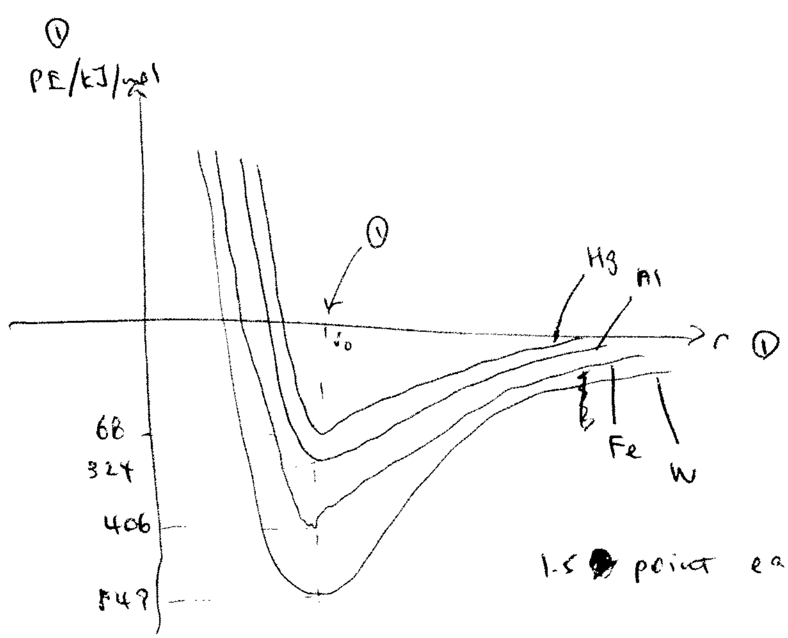
Ar

Xe

2 points

B) Sketch a graph of potential energy vs. interatomic distance of the metals listed below using the bonding energies provided and assuming that the metals listed below have similar equilibrium spacing, r_0.

Hg	68 kJ/mol
Al	324 kJ/mol
Fe	406 kJ/mol
W	849 kJ/mol



1.5 point each for line = 6

C) List the metals from part (B) in order of increasing stiffness. Explain your answer.

Hg < Al < Fe < W (1)

using the simple spring model, the stronger the bond, the harder it will be to stretch atoms apart. Increasing bond strength will increase stiffness. (2)

D) List the metals from part (B) in order of increasing thermal expansion coefficients. Explain your answer.

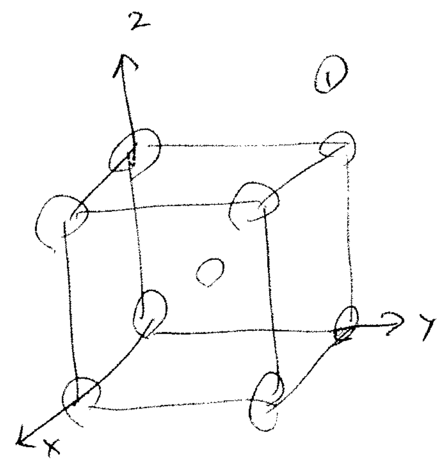
W < Fe < Al < Hg (2)

Large thermal expansion coefficient means that atoms can be stretched apart more easily. Therefore increase in bond strength will lead to a decrease in thermal expansion coefficient.

(2)

Problem 3 (18 points):

A) Show that the atomic packing factor for BCC is 0.68.



$$APF = \frac{\text{volume of atoms in unit cell}}{\text{volume of unit cell}}$$ (1)

No. of atoms in unit cell $= \frac{1}{8} \times 8 + 1 = 2$ (2)

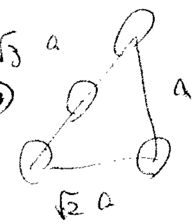
$$APF = \frac{2 \times \frac{4}{3}\pi R^3}{a^3}$$

$$= \frac{8}{3}\pi \left(\frac{\sqrt{3}}{4}\right)^3 \approx 0.68$$ (3)

QED.

$4R = \sqrt{3}\, a$

(3)



B) Molybdenum has a BCC crystal structure, an atomic radius of 0.1363 nm and an atomic weight of 95.94 g/mol. Calculate its theoretical density.

$$\rho = \frac{M}{V} = \frac{\text{no. of atoms in unit cell} \times \text{mass of atom}}{V}$$ (1)

$$= \frac{2 \times \frac{AW}{N_A}}{V} = \frac{\frac{2 \times 95.94\ g/mol}{6.022 \times 10^{23}\ atoms/mol}}{a^3}$$ (2)

$a = \frac{4R}{\sqrt{3}}$; $\rho = 10.21\ g/cm^3$

(3) (2) for units

Problem 4 (18 points):

A) With all other parameters being equal, how would you expect the ductility of a metal to depend on the number of dislocations? Explain your answer with a few words.

Ductility is a measure of how many dislocations you can fit in a material. (4)

Therefore, ductility will decrease with increasing no. of dislocations.

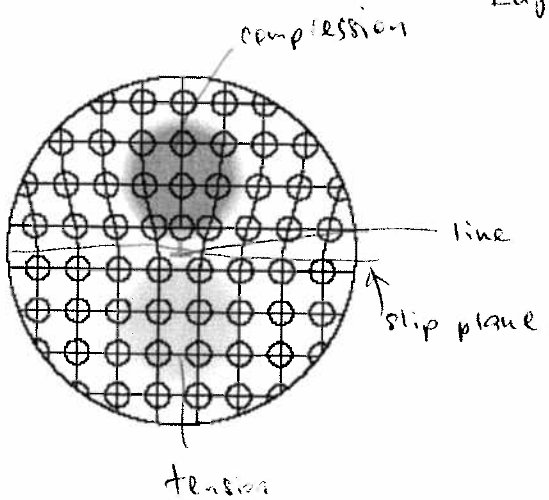
B) Complete the following sentence:

Virtually all strengthening strategies rely on the simple principle that……

plastic deformation occurs as a result of dislocation motion. (4)

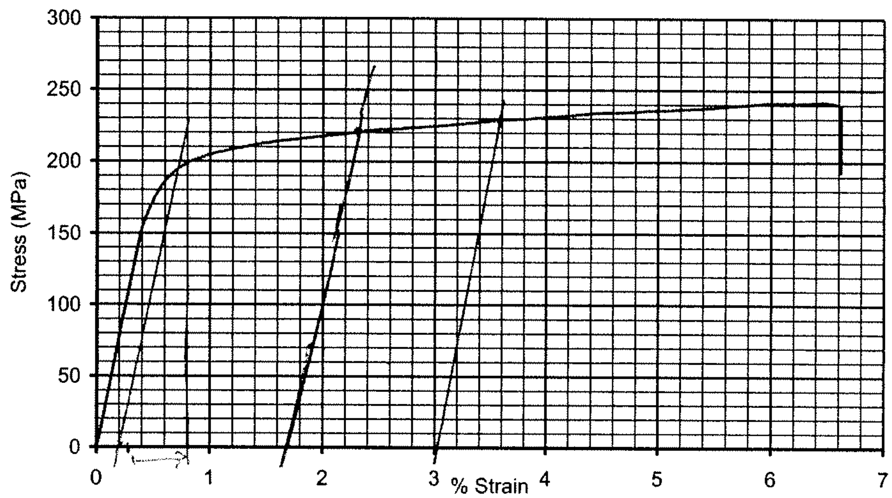
C) Indicate the type the dislocation below, and label the dislocation line and slip plane. Indicate the type of stress above and below the slip plane.

Edge (2) each.



Problem 5 (18 points):

Below is stress-strain curve for a cylindrical sample which is 10 mm long and has a diameter of 1 mm.



A. Determine the 0.2% offset yield strength. Show your work.

195 MPa

(2) (1)

B. What is the elastic modulus? Show your work.

$\sigma = E\varepsilon \qquad E = \frac{\sigma}{\varepsilon} = \frac{150 \text{ MPa}}{0.4\ \%} = 37.5 \text{ GPa}$

(2) (1)

C. Determine the permanent strain if the sample if subjected to 50 MPa and then unloaded.

0 (2)

D. What stress is required to produce a plastic deformation of 3%? Show your work.

230 MPa

(2) (1)

E. Estimate the elastic strain at 200 MPa stress.

$\sim 0.3\%$

(2)

F. If you applied 220 MPa tensile stress to a cylindrical rod 0.5 m long with 5 cm diameter, how long would the rod be after the stress was removed.

1.7% strain. (1)

$$\varepsilon = \frac{\Delta l}{l} \Rightarrow \Delta l = \varepsilon l$$

$$= 0.017 \times 0.5 \text{ m}$$

$$= 85 \times 10^{-4} \text{ m}$$

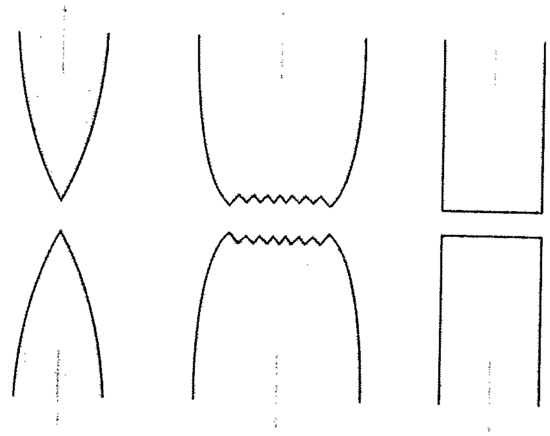
$$= 8.5 \text{ mm} \quad (1)$$

∴ Final length = 0.5085 m

(2) (1)

Problem 6 (18 points):

A) Below are schematic representations of 3 types of fractures due to tensile stress.



(a) (b) (c)

Rank the ductility of the specimens a, b, and c. On what criteria did you base your ranking?

(a) > (b) > (c) ①

Based on the degree of plastic deformation before fracture. ①

B) Describe and explain the changes occurring to the microstructure of a metal during the 3 stages during creep.

① Instantaneous + primary creep

Initial elastic deformation followed by plastic deformation. Dislocations being created. ②

② Secondary (steady-state) creep.

Steady creep rate because of simultaneous annealing and plastic deformation. ②

Rate of formation and disappearance of dislocations is balanced.

③ Tertiary creep.

Material fails. ②

C) Steady-state creep data taken for an iron sample at a stress level of 140 MPa are given here:

$\dot{\varepsilon}_s$ (h^{-1})	T (K)
6.6×10^{-4}	1090
8.8×10^{-2}	1200

If it is known that the value of the stress exponent n for this alloy is 8.5 and $Q_C = 4.83 \times 10^5$ J/mol, compute the steady-state creep rate at 1300 K and a stress level of 83 MPa.

$$\dot{\varepsilon}_s = K_2 \sigma^n \exp\left(-\frac{Q_c}{RT}\right)$$

$R = 8.314$ J/mol K

$$K_2 = \frac{\dot{\varepsilon}_s}{\sigma^n \exp\left(-\frac{Q_c}{RT}\right)}$$

(2)

$$= \frac{6.6 \times 10^{-4}\ h^{-1}}{(140\ MPa)^{8.5}} \times \exp\left(\frac{4.83 \times 10^5\ J/mol}{8.314\ J/mol K \cdot 1090\ K}\right)$$

$$= 53\ h^{-1}\ (MPa)^{-8.5}$$

(2) (2)

$$\dot{\varepsilon}_s = K_2 \sigma^n \exp\left(-\frac{Q_c}{RT}\right)$$

$$= 53\ h^{-1}\ \cancel{(MPa)^{-8.5}}\ 83^{8.5} \exp\left(-\frac{4.83 \times 10^5}{1300 \times 8.314}\right)$$

$$= 4.3 \times 10^{-2}\ h^{-1}$$

(2) (2)

Equations:

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

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

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

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

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

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

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

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

$$\dot{\varepsilon}_s = K_2 \sigma^n e^{-\frac{Q_c}{RT}}$$

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

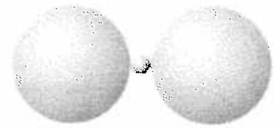
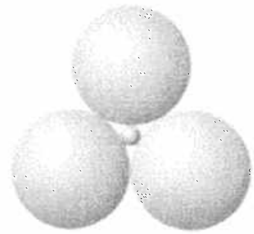
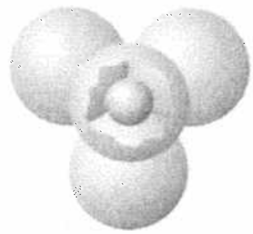
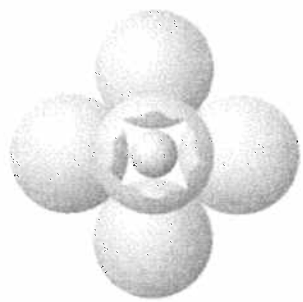
$k = 1.38 \times 10^{-23}$ $m^2kgs^{-2}K^{-1}$ $= 8.62 \times 10^{-5}$ eV/K

R = 8.314 J/molK

IA	IIA	IIIB	IVB	VB	VIB	VIIB	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

Coordination Number	*Cation–Anion Radius Ratio*	*Coordination Geometry*
2	<0.155	
3	0.155–0.225	
4	0.225–0.414	
6	0.414–0.732	
8	0.732–1.0