MSE 170 A Midterm 11/2/2009 100pts. Total
Exam is closed book, closed notes, no collaborations with neighbors.

(Two sheets of letter-size paper is allowed)

Instructions:
1. *Write your name and student ID on the top of the page.*
2. *Read the questions carefully.*
3. *Read the questions carefully, again.*
4. *Make sure you are answering the right questions.*
5. *Write legibly.*
6. *Show work as needed to justify answers.*
7. *After you are done, hand in your work and as once a wise man said: " Do a little dance, ..."*

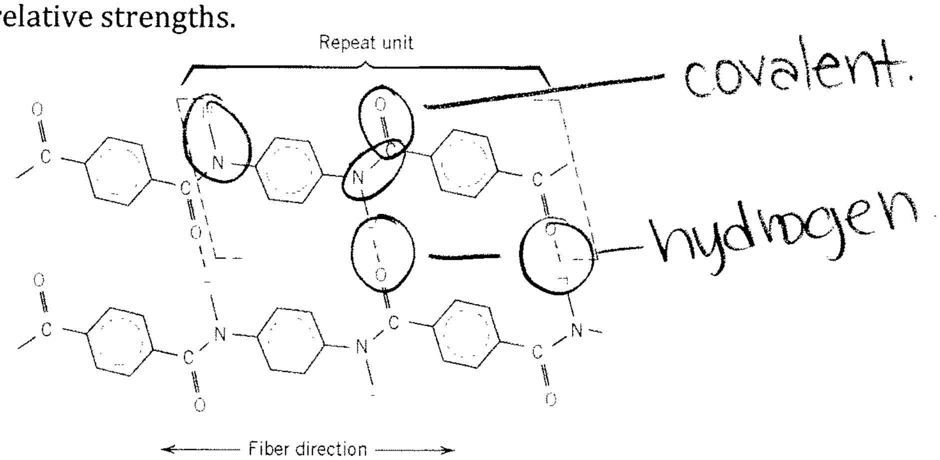
GOOD LUCK!

Point Distribution (total=100)

Problem 1	*50*
Problem 2	*25*
Problem 3	*25*

Problem 1. Basic concepts (50 points): Answer the following questions:

1. What kind of atomic and intermolecular bonds exist in Kevlar? Comment on their relative strengths.



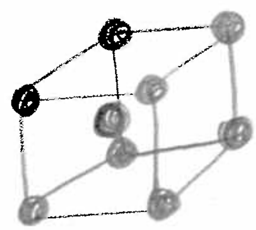
a.

covalent bond stronger than hydrogen bond.

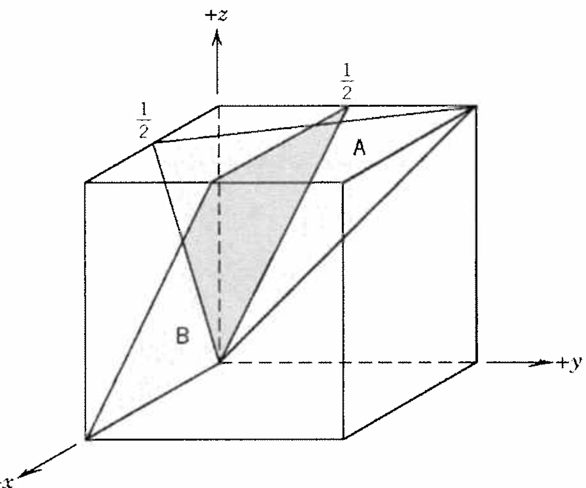
2. What differentiates a crystalline structure from an amorphous one?

A crystalline structure has long range order OR repeating unit cell OR translational invariance.

3. Draw a unit cell for a BCC structure.



4. Determine the Miller indices for the planes A and B shown in the following unit cell.



A intercepts: $\frac{1}{2}$ 1 −1
reciprocals: 2 1 −1
indicies: $(2\,1\,\bar{1})$

B intercepts: ∞ $\frac{1}{2}$ −1
reciprocals: 0 2 −1
indicies: $(0\,2\,\bar{1})$

5. What defect plays a major role in influencing the plastic deformation of metals? Explain.

Dislocations

During plastic deformation, dislocations move. As a consequence, planes slip on top of each other

6. Referring to the periodic table on page 11, determine what is the predominant type of bonding for SiC (Silicon Carbide), LiCl (Lithium Chloride), and solid Mo. Why?

SiC	covalent	small difference in electronegativities.
LiCl	ionic	big difference in electronegativities.
Mo	metallic	elemental metal donates electrons to "sea of electrons"

7. All other parameters being equal, how would you expect the ductility of a metal to depend on the number of dislocations? Consider the cases of some dislocations, and a large number of dislocations. Explain your answer with a few words.

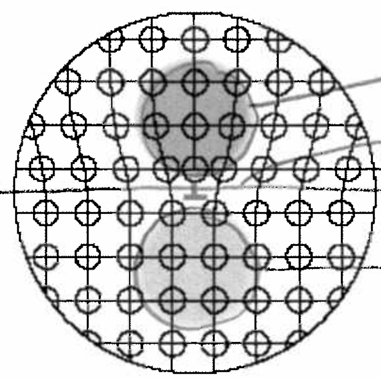
- Some dislocations: ductile, dislocations move and contribute to plastic deformation
- large no. of dislocations: brittle, dislocation motion is impeded → no plastic deformation

8. Complete the following sentence:
    a. Virtually all strengthening strategies rely on this simple principle:

impede dislocation motion

9. 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 dislocation



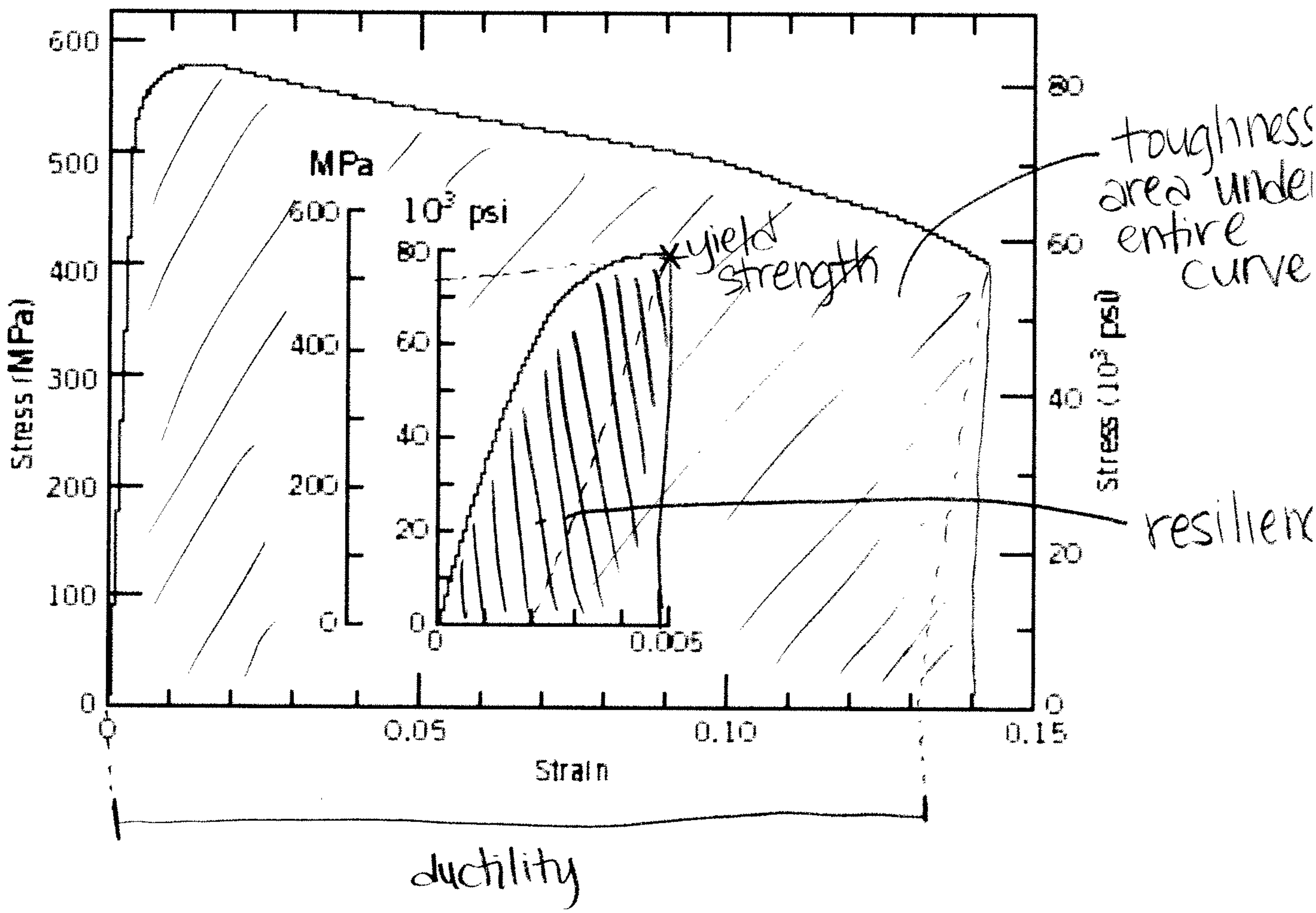
a.

10. List three allotropes of carbon.

- graphite
- diamond
- C_{60} fullerene
- carbon nanotubes (CNT)
- graphene
- amorphous carbon

Problem 2. (25 points) From the stress-strain plot for a plain carbon steel shown in the figure below:

(a) Label in the following figure the yield strength, resilience, toughness, and ductility (10 points)



(b) A steel bar 100 mm long with a square cross section of 20 mm × 20 mm is pulled in tension with a load of 100 kN, and experiences an elongation of 0.10 mm. Calculate the elastic modulus of the steel for the given conditions if the deformation is entirely elastic. (10 points)

$$\sigma = \frac{100 \times 10^3 \text{ N}}{(20 \times 10^{-3} \text{m} \times 20 \times 10^{-3} \text{m})} = \frac{100}{400} \times 10^3 \text{Pa}$$

$$= 250 \text{ MPa}$$

$$\varepsilon = 0.001$$

$$\sigma = E\varepsilon$$

$$E = \frac{\sigma}{\varepsilon}$$

$$E = \frac{250 \text{MPa}}{0.001}$$

$$\boxed{E = 250 \text{GPa.}}$$

(c) Calculate the elastic modulus from the figure and compare the result with that obtained from (b). (5 points)

From figure (E is slope of elastic portion of the curve)

$E \approx 230 \pm 30$ GPa.

E from figure seems smaller

Problem 3 (25 points) Diffusion

a. Given Fick's first law of diffusion $J = -D\frac{dC}{dx}$ define all the quantities present in the equation and state which assumption was made to derive it (10).

J : flux = material per unit area in unit time

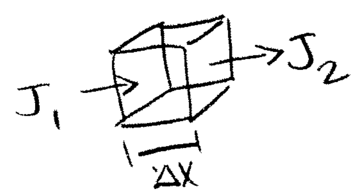
D : diffusion coefficient.

$\frac{dC}{dx}$: concentration gradient = change in concentration in space.

assumption: steady state <u>OR</u> time independency.

b. Explain how Fick's second law $\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2}$ can be derived from Fick's first law by making a few simple physical arguments (no need to derive). Think about the meaning of C and J and how they relate to each other in time. (10)

- Assume mass conservation.
- change of concentration per unit volume per unit time = mass in − mass out
  ≈ flux



- think of a small volume $A\,dx$. $J_2 - J_1$ is equal to dJ/dx
- from Fick's first law, we know J
- differentiate J and obtain Fick's 2nd law

c. Qualitatively describe the dependence of D on temperature and explain how this dependence relates to Q_d (diffusion activation energy) (3). Would you expect case hardening of a gear to proceed faster at 500 C or 700 c? (2)

high T — thermally activated
bigger D

Q_d is the energy of thermal activation.
For the same T, the thermal part of diffusion is smaller for bigger Q_d.

OR

$J \sim e^{-Q_d/RT}$

Case hardening involves the diffusion of C. Faster at 700°C (higher T) than 500°C (lower T).

Periodic Table

Key: 29 — Atomic number; Cu — Symbol; 63.54 — Atomic weight

Metal

Nonmetal

Intermediate

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII			IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
1 H 1.0080																	2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.064	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.87	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.69	29 Cu 63.54	30 Zn 65.41	31 Ga 69.72	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.34	Rare earth series	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.2	76 Os 190.23	77 Ir 192.2	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.19	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	Acti-nide series	104 Rf (261)	105 Db (262)	106 Sg (266)	107 Bh (264)	108 Hs (277)	109 Mt (268)	110 Ds (281)								

Rare earth series	57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.35	63 Eu 151.96	64 Gd 157.25	65 Tb 158.92	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
Actinide series	89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Electronegativity

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															