Department of Materials Science and Engineering
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MSE 104, LEC. 1 Final Exam
Spring 2022, June 7, 3-6pm

NAME: ______________________________

UCLA ID: ____________________________

All work must be clearly shown with proper units in the final answer to receive full credit.

Please write on front of page only – extra paper will be provided if you need it.

1 (20 pts)	
2 (10 pts)	
3 (10 pts)	
4 (14 pts)	
5 (12 pts)	
6 (14 pts)	
7 (10 pts)	
8 (10 pts)	
Total	

Problem 1 (20 pt)

I. Which of the following polymers may be recycled? (2 pts)
   (a) Billiard balls made from phenol-formaldehyde resin
   (b) Plastic wrap
   (c) Vulcanized natural rubber

II. With increasing temperature, indicate the change of the following material properties (increase, decrease or does not change). (6 pts)
   i: Viscoelastic modulus in polystyrene________________________
   ii: Resistance of Aluminum ________________________

III. For steels: (2 pts)
   (a) Tempering is a process of heating the martensitic steel to gain ductility
   (b) Pearlitic steels are stronger than tempered martensite.
   (c) Martensitic steels are formed by water quenching
   (d) Bainite is stronger than fine pearlite

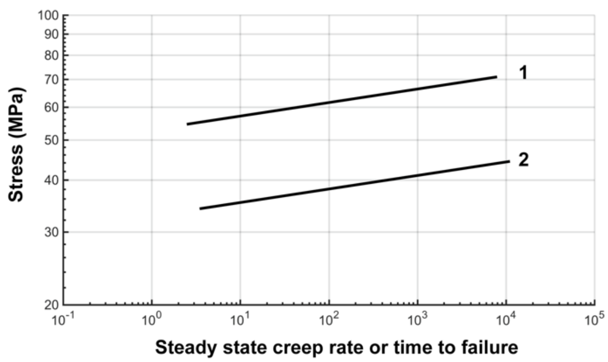
IV. Which of the following are strengthening mechanisms NOT available for binary Ni-Cu alloys: (2 pts)
   (a) precipitation hardening
   (b) grain size strengthening
   (c) solid-solution strengthening
   (d) strain hardening/cold-working

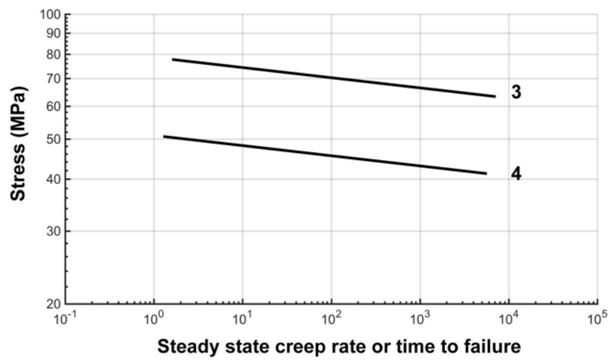
V. The mobilities of semiconductors and metals (2 pts)
   (a) Increase with increasing temperature
   (b) Decrease with increasing temperature
   (c) Semiconductor mobility increases, metal mobility decreases with increasing temperature
   (d) Exhibits no temperature dependence

VI. Which of the following processes involve thermal activation energy (2 pts)
   a. intrinsic conduction in semiconductors
   b. steady state creep rate
   c. cold work

VII. Shown below are two creep-related graphs, both have stress as the y-axis. The x-axis (arbitrary units) is either the steady-state creep rate (creep strain per time) OR the time to failure. (4 pts).

VIII. For lines 1&2, specify whether the x-axis is steady-state creep rate or time to failure
IX. For lines 1&2, specify whether line 1 or line 2 is for the higher temperature
X. For lines 3&4, specify whether the x-axis is steady-state creep rate or time to failure
XI. For lines 3&4, specify whether line 3 or line 4 is for the higher temperature





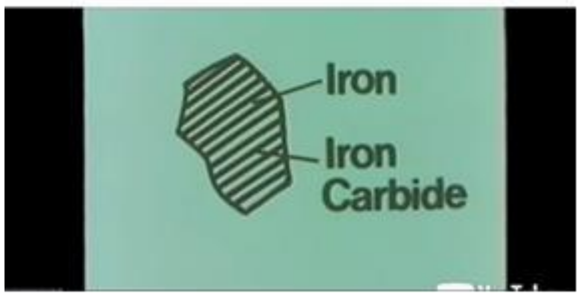
<u>Problem 2 Short answers (10 pt)</u>

1.(2 pts) Plot typical (qualitative) S-N curves for steels and for non-ferrous alloys. Mark the fatigue limit and the fatigue strength on the appropriate plot.

2.(2 pts) Describe the 3-point bend test as a mean to determine mechanical properties of brittle materials

3.(3 pts) Explain (2-3 sentences) whether bending a paper clip until it breaks is an example of fatigue. If not, what is it an example of?

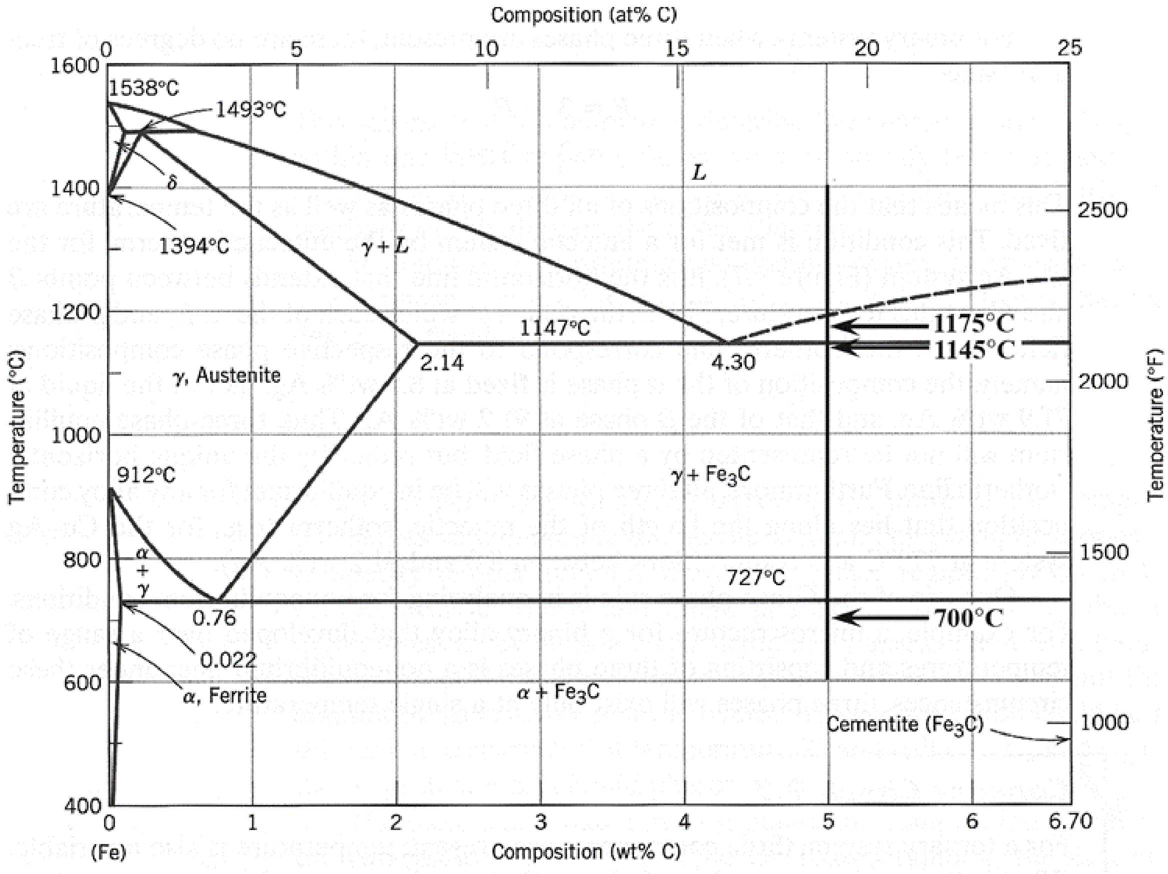
4.(3 Pts) Steel is described as containing (at equilibrium, at room temperature)two different types of grains, ferrite (bcc) and the one shown below:



This type of grain is referred to as_________________________and consist of these phases:____ and_________________________(names other than 'iron' and 'iron carbide').

Problem 3: **(10 pt) Phase Diagram**

The Fe-C phase diagram is shown below:



a) Identify the equilibrium phases present at 725 ºC (after cooling down from the austenite phase region) in the following steels: (6 points)

- Fe- 0.38 wt.% C :
- Fe- 0.76 wt.% C :
- Fe- 1.4 wt.% C :

(2 pts each phase)

b) Consider 2.0 kg of a 99.6 wt% Fe–0.4 wt% C alloy that is cooled to a temperature just below the eutectoid. (i) How many kilograms of proeutectoid ferrite form? (ii) How many kilograms of eutectoid ferrite form? (4 points)

<u>Problem 4</u> (14 pts) Diffusion & Electrical Properties

Silicon (Si) is to be doped with Boron (B) such that the extrinsic semiconductor has a room temperature electrical conductivity of 0.08 $(\Omega m)^{-1}$. To achieve this, B atoms are diffused into a pure crystalline Si wafer using a heat treatment conducted at 900°C for 286.5 hours. The surface concentration of B is to be maintained at a constant level of $3.0x10^{24}$atoms/m^3. The values of activation energy and pre-exponential are 3.87eV/atom and $2.4x10^{-3}m^2$/s, respectively. Si has a density of 2.33g/cm^3, an intrinsic conductivity of $4x10^{-4}$ $(\Omega m)^{-1}$, with $\mu_e = 0.19\ m^2$/Vs. B has a density of 2.34 g/cm^3. Assume that B atoms substitute for Si atoms and saturation is reached.

(i.) Find the concentration of B in Si at a depth of 1.0μm from the surface. (6pts)

(ii.) Assuming the value from (i) to be the equilibrium concentration of B in Si, find:

a. The atomic % of B in the Si sample.(4pts)
b. The charge carrier mobility of this sample. (Hint: what is the dominant charge carrier in this extrinsic semiconductor?) (4pts)

The electrical conductivity of this sample if it was further doped with an additional $5x10^{18}$atoms/m^3B.

<u>Problem 5.</u> (12 pt) Mechanical Properties

(a) Copper and nickel form a binary isomorphous system. Pure copper has a tensile strength ~220 MPa and pure nickel has a tensile strength ~340 MPa. For a 50 wt% Cu and 50 wt% Ni alloy, which of the following do you expect for the tensile strength and for ductility and explain why. (4 pts)

Tensile strength	Ductility
i. Tensile strength less than pure Cu	i. Ductility less than pure Cu
ii.Tensile strength between pure Cu and pure Ni	ii. Ductility between pure Cu and pure Ni
iii. Tensile strength higher than pure Ni	iii. Ductility higher than pure Ni

(b) A structure component is to be fabricated from a metal alloy with a plane-strain fracture toughness of 25 MPa-m$^{1/2}$ and a yield strength of 860 MPa. The flaw size detection limit of the equipment is 3.0 mm. If the design stress is one half of the yield strength and Y=1.0, determine whether a critical flaw for this component is subject to detection. (8 pt)

<u>Problem 6. (14 pt)</u> Polymer

a. Molecular weight data for some polymer A are tabulated here. Compute (a) the number-average molecular weight (3 pts), (b) the weight-average molecular weight (3 pts). (c) If the degree of polymerization is 560 what is the repeat unit molecular weight m (3 pts).

Molecular Weight Range g/mol	x_i	w_i
15,000–30,000	*0.04*	*0.01*
30,000–45,000	*0.07*	*0.04*
45,000–60,000	*0.16*	*0.11*
60,000–75,000	*0.26*	*0.24*
75,000–90,000	*0.24*	*0.27*
90,000–105,000	*0.12*	*0.16*
105,000–120,000	*0.08*	*0.12*
120,000–135,000	*0.03*	*0.05*

b. (i) On a relaxation modulus (y-axis) vs temperature (x-axis) graph, clearly plot two curves for polyethylene with 30% crystallinity and 50% (2 pts), (ii) clearly mark curves and each characteristic points(3pt).

Problem 7 Composites (10pts)

A continuous and aligned fiber-reinforced composite is to be produced consisting of 30 vol% aramid fibers and 70 vol% of a polycarbonate matrix; mechanical characteristics of these two materials are as follows:

	Modulus of Elasticity [*GPa* (*psi*)]	*Tensile Strength* [*MPa* (*psi*)]
Aramid fiber	*131 (19×10^6)*	*3600 (520,000)*
Polycarbonate	*2.4 (3.5×10^5)*	*65 (9425)*

Also, the stress on the polycarbonate matrix when the aramid fibers fail is 45 MPa (6500 psi).

For this composite, compute the following:

(a) (5 pts) the longitudinal tensile strength, and

(b) (5pts) the longitudinal modulus of elasticity

<u>Problem 8</u> (10 pts) Optical properties

A bulk CdSe p-n junction can be made into an LED emitting at 730 nm. Explain whether this material is opaque, transparent or colored in transmission. (Note: the photon energies, $h\nu$, for red and blue lights are 1.8 and 3.1 eV, respectively)

Useful equations, tables and constants:

$N_A = 6.02 \times 10^{23}$ atoms/mole

Boltzman's constant k = 8.62×10^{-5} eV/atom-ºK

Boltzman's constant R = 8.31 J/mol-ºK

Electron charge |e| = |h| = 1.602×10^{-19} C

Planck's constant, h = 4.13×10^{-15} eV-s

Speed of light in vacuum, c = 3.0×10^{8} m/s

10^{9} = giga

10^{6} = mega

10^{3} = kilo

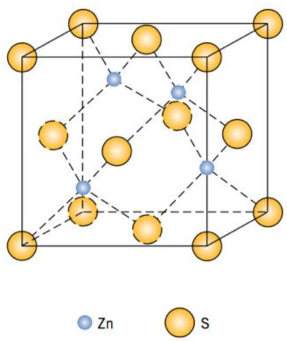
10^{-2} = centi

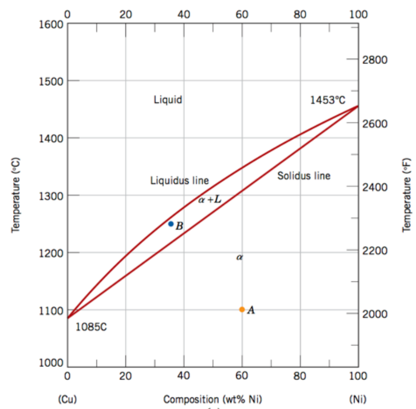
10^{-3} = milli

10^{-6} = micro

10^{-9} = nano

10^{-12} = pico





$$a = 2R\sqrt{2} \qquad a = \frac{4R}{\sqrt{3}} \qquad APF = \frac{V_S}{V_C}$$

$$\rho = \frac{nA}{V_C N_A} \qquad N_v = N_o \exp\left(-\frac{Q_v}{kT}\right) \qquad \sigma_T = \sigma(1+\varepsilon) \qquad \varepsilon_T = \ln(1+\varepsilon)$$

$$\sigma = \frac{F}{A_o} \qquad \varepsilon = \frac{l - l_o}{l_o} = \frac{\Delta l}{l_o} \qquad \sigma = E\varepsilon \qquad \tau = G\gamma$$

$$\nu = -\frac{\varepsilon_x}{\varepsilon_z} = -\frac{\varepsilon_y}{\varepsilon_z} \qquad E = 2G(1+\nu) \qquad \sigma_m = 2\sigma_o\left(\frac{a}{\rho_t}\right)^{1/2} \qquad \sigma_c = \left(\frac{2E\gamma_s}{\pi a}\right)^{1/2}$$

$$\%EL = \left(\frac{l_f - l_o}{l_o}\right) \times 100 \qquad U_r = \frac{1}{2}\sigma_y\varepsilon_y = \frac{\sigma_y^2}{2E} \qquad K_c = Y\sigma\sqrt{\pi a} \qquad K_{Ic} = Y\sigma\sqrt{\pi a}$$

$$\dot{\varepsilon}_s = K\sigma^n \exp\left(-\frac{Q_c}{RT}\right) \qquad \frac{C_x - C_o}{C_s - C_o} = 1 - erf\left(\frac{x}{2\sqrt{Dt}}\right) \qquad D = D_o \exp\left(-\frac{Q_d}{RT}\right)$$

C = Q/V   E = V/l   p=qd   P = Σqd/V_c

C = ε_oA/l (vacuum)   C = εA/l (dielectric material) $\varepsilon_r = \varepsilon/\varepsilon_o$

$\eta \approx (\varepsilon_r)^{1/2}$ index of refraction for non-magnetic materials

$D_o = \varepsilon_o E$ (vacuum) $D = \varepsilon E = \varepsilon_o E + P$ (dielectric material)

$\sigma = 1/\rho$ Metals: $\sigma = n|e|\mu_e$ Semiconductors: $\sigma_{total} = n|e|\mu_e + p|e|\mu_h$

$n_i = n_o \exp(-E_g/2kT)$, $p_i = p_o \exp(-E_g/2kT)$ $\sigma \approx \sigma_o \exp(-E_g/2kT)$, $p_o = n_o$

$n \approx n_o \exp(-\Delta E/kT)$, $p \approx p_o \exp(-\Delta E/kT)$ $\sigma \approx \sigma_o \exp(-\Delta E/kT)$ $E = h\nu = hc/\lambda$

$$\overline{M}_n = \sum x_i M_i \quad \overline{M}_w = \sum w_i M_i \quad DP_n = \sum x_i n_i = \frac{\overline{M}_n}{\overline{m}}, \; DP_w = \sum w_i n_i = \frac{\overline{M}_w}{\overline{m}}, \overline{m} = \Sigma f_i m_i \qquad E_r(t) = \frac{\sigma(t)}{\varepsilon_o}$$

$$lc = \frac{\sigma^*_f \, d}{2\tau_c} \qquad E_c = E_m V_m + E_f V_f, \qquad \frac{1}{E_{ct}} = \frac{V_m}{E_m} + \frac{V_f}{E_f}$$

$(l>15l_c)$: $\sigma^*_c = \sigma^*_f V_f + \sigma'_m(1-V_f)$; $(l_c<l<15l_c)$: $\sigma^*_c = \sigma^*_f V_f (1 - l_c/2l) + \sigma'm (1-V_f)$,

$(l<l_c)$ $\sigma^*_c = (l\tau_c/d) V_f + \sigma'_m (1-V_f)$

z	***erf(z)***	*z*	***erf(z)***	*z*	***erf(z)***
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999

Metal

Nonmetal

Intermediate

Atomic Weight: g/mol

Key: 29 (Atomic number), Cu (Symbol), 63.54 (Atomic weight)

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	IIIA	IVA	VA	VIA	VIIA	0
1 H 1.0080																	2 He 4.0026
3 Li 6.939	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 20.183
11 Na 22.990	12 Mg 24.312											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 39.102	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.91	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 (99)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.40	49 In 114.82	50 Sn 118.69	51 Sb 121.75	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 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.37	82 Pb 207.19	83 Bi 208.98	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	Acti-nide series															

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