UNIVERSITY OF CALIFORNIA AT BERKELEY — DEPARTMENT OF CEE
FALL SEMESTER, 2022 — Instructor: P.J. M. Monteiro

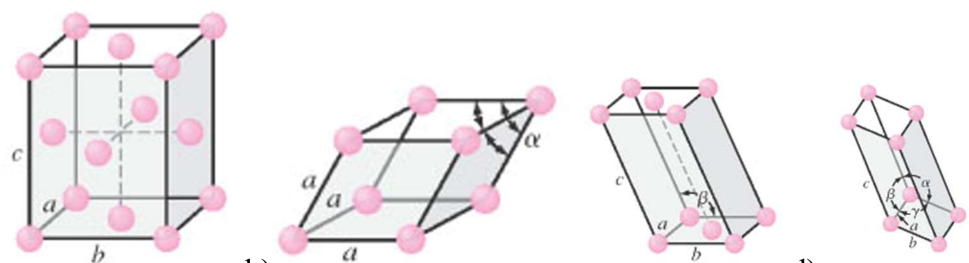
Name: ____________________

# CE 60 – EXAMINATION

**Please justify all your answers**

**Question 1** (26 points)

I) Identify the following crystal structures: (16 points)




a) b) c d)

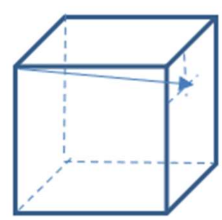
**a) orthorhombic, face centered**
**b) rhombohedral**
**c) monoclinic**
**d) triclinic**

II) Define the Miller indices for the following: (10 points)

a) A direction vector passes through a unit cube from the $\left(\frac{3}{4}, 0, \frac{1}{4}\right)$ to the $\left(\frac{1}{2}, 1, 0\right)$ positions.

tip: 0.5 1 0
-base: 0.75 0 0.25

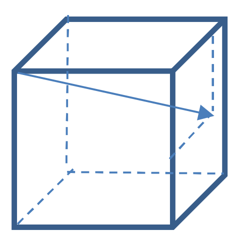
-0.25 1 -0.25 $[\bar{1}, 4, \bar{1}]$



b) A direction vector passes through a unit cube from the $\left(1, 0, \frac{3}{4}\right)$ to the $\left(\frac{1}{4}, 1, \frac{1}{4}\right)$ positions.

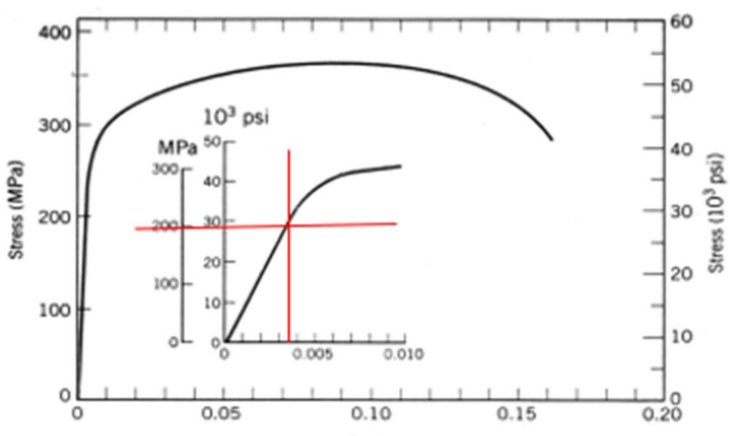
tip: 0.25 1 0.25
-base: 1 0 0.75

-0.75 1 -0.5 $[\bar{3}, 4, \bar{2}]$



Question 2 (29 points)

I) Consider the engineering stress-engineering strain diagram for an aluminum alloy. (20 points)




Estimate elastic modulus:
E = 200 MPa/0.0033
= around 60,000 MPa

a) The specimen was loaded to 320 MPa and then unloaded to 250 MPa. How much elastic strain is recovered? (10 points)

**Recovery using approximate E:**
**$\varepsilon_{recovery}$=(320 MPa-250 MPa)/60,000 MPa = 0.0011**

b) In another experiment, the specimen was loaded to 330 MPa and then fully unloaded. Estimate the yield point, once the specimen is loaded again. (5 points)

**330 MPa**

c) The stress-strain diagram shows that the alloy reached a maximum stress and then it starts to decrease. Please explain the reason. (5 points)

**Beyond ultimate (maximum) stress, necking occurs, and the specimen decreases cross sectional area drastically. This effectively causes the sample to unload and the engineering stress, which is defined by the original unloaded cross-sectional area, decreases. True stress, however, continues to increase until fracture.**

II) Martensite in pure iron is cubic but in steel is tetragonal. Explain the reason. (5 points)

**Steel, unlike pure iron, contains carbon. These carbon atoms are unable to diffuse out of austenite during quenching, effectively elongating the unit cell.**

III) Explain the concept of critical radius in homogeneous nucleation (4 points)

**Critical radius, r*, is the radius of particle cluster that is suspended in its liquid phase where the sum of its surface free-energy change (retarding energy) and volume free-energy change (driving energy) is at maximum. If the cluster radius is less than the critical radius, nucleation will not occur. If the cluster radius is greater than the critical radius, nucleation will occur.**

Question 3: (45 points)
Consider the steel phase diagram shown below:

I) For eutectoid steel, what is the composition of austenite at 900 °C? (5 points)

Exactly eutectoid composition (**0.8% C, 99.2% Fe**)

II) A hypoeutectoid steel just below the eutectoid temperature contains 4.2% cementite. Compute: a) the amount of pearlite, b) the amount of proeutectoid ferrite, c) the amount of proeutectoid cementite (15 points)

Alloy composition calculation. Using lever rule at $723^{o}C-\Delta T$:

wt% cementite = 0.042 as given
wt% cementite = (x-0.02)/(6.67-0.02) lever rule

solving for x,

x= 0.3 wt% C (99.7 wt% Fe)

b) (wt% proeutectoid ferrite at $723^{o}C-\Delta T$) = (wt% proeutectoid ferrite at $723^{o}C+\Delta T$)
(wt% proeutectoid ferrite at $723^{o}C+\Delta T$) = (0.8-0.3)/(0.8-0.02) =**0.641 (64%)**

a) (wt% pearlite at $723^{o}C-\Delta T$) = (wt% of liquid above eutectoid pt)
(wt% of liquid above eutectoid pt) = (0.3-0.02)/(0.8-0.02) = **0.359 (36%)**

alternatively,

(wt% pearlite at $723^{o}C-\Delta T$) = (wt% of all phases present except proeutectoid phases)
as a hypoeutectoid steel, the only proeutectoid phase present is proeutectoid ferrite which was computed already.
(wt% pearlite at $723^{o}C-\Delta T$)=1-0.641 = **0.359 (36%)**

c) **0%; hypoeutectoid steel does not produce proeutectoid cementite**

III) At 800 °C, a steel contains 40% of proeutectoid ferrite. Is the steel hypo or hypereutectoid? (5 points). Hypoeutectoid. Compute the composition and the weight percentage of austenite at 750 °C (10 points)
composition calculation (approximate):

wt% $_{\text{proeutectoid ferrite at } 800^{o}C}$ = (0.44-x)/(0.44-0.01) = 0.4; x= 0.268% C

composition $_{\text{austenite at } 750^{o}C}$ (approximate): **0.62% C, 99.38% Fe** wt % austenite at 750°C : (0.268-0.016)/(0.62-0.016)= **0.417 (41.7%)**

IV) Why is pearlite not shown in the phase diagram? (5 points)

**Pearlite itself is not a phase – rather, it is a composite of thin stripes two phases (eutectoid ferrite and eutectoid cementite) stacked on top of each other.**

V) Why is martensite not shown in the phase diagram? (5 points)

**Phase diagram assumes a slow rate of cooling. Martensite can only be produced when rate of cooling is fast.**