UNIVERSITY OF CALIFORNIA AT BERKELEY
FALL SEMESTER, 2019

DEPARTMENT OF CEE
Instructor: P.J. M. Monteiro

Name: ____________________

CE 60 – EXAMINATION

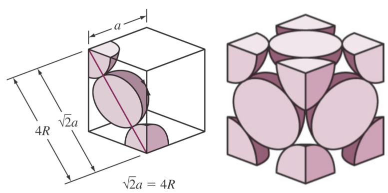
<u>Please justify all your answers</u>

Question 1 (29 points)

I) Calculate the atomic packing factor for the FCC structure (6 points)

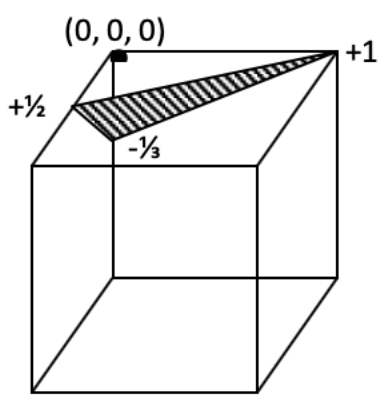
$\sqrt{2}\,a = 4R$

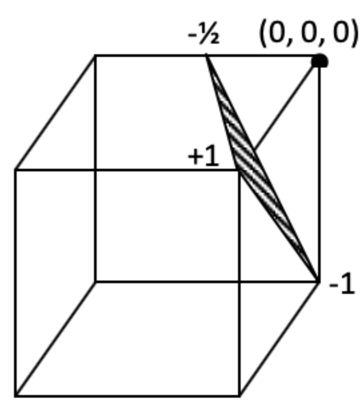
$$PF = \frac{4*\left(\frac{4}{3}\right)*\pi*R^3}{a^3} = \frac{\sqrt{2}\pi}{6} = 74\%$$



(4 atoms in FCC unit cell)

II) Define the Miller indexes for the following planes: (8 points)

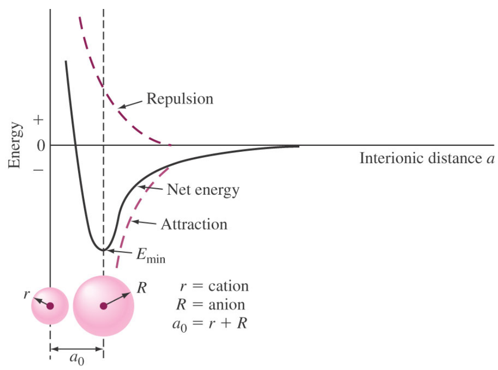


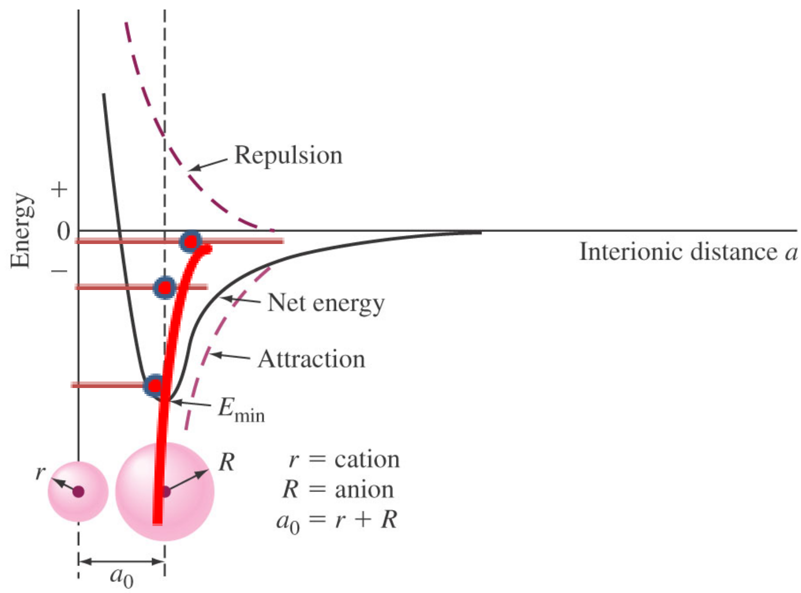


(2, 1, $\bar{3}$)

(1, $\bar{2}$, $\bar{1}$)

III) Using the energy plot shown below, explain why materials tend to expand with increasing temperatures. (10 points)





Net energy increases with the increasing of temperature. Because the curve of net energy-interionic distance is anharmonic, as shown in the figure, the mean value of interionic distance increase. The materials tend to expand.

IV) What is the risk of heating a cup of water in a microwave oven? (5points)

(1) Water can be superheated (above its normal boiling point).
(2) When you open the microwave oven and take the cup, bubbles of water vapor suddenly form and release. Water boil and “explode”.

Question 2 (36 points)

I) In class we briefly discussed the collapse of the Twin Towers. When there is a phase change, a material can expand or contract. Let's see what happens when pure iron is exposed to increasing temperatures. Calculate the change in volume that occurs when BCC iron is heated and changes to FCC iron. The lattice parameter of BCC iron is 0.2863 nm and of FCC iron is 0.3591 nm (12 points)

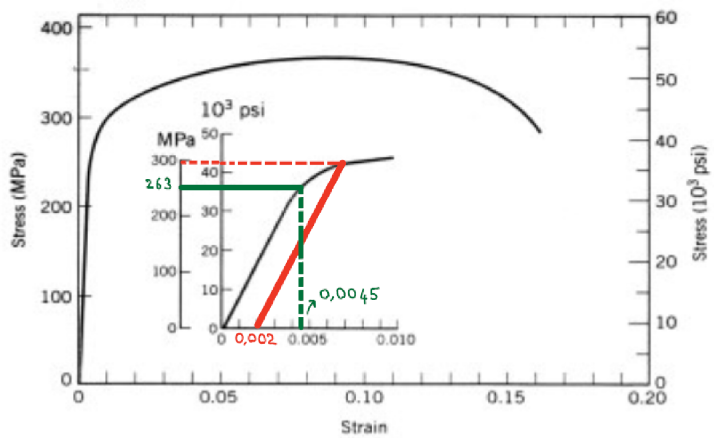
Compare volumes which have the same number of atoms. FCC lattice has 4 atoms while BCC has 2 atoms. Therefore, two BCC unit cells would contain 4 atoms.

$$2 \times V_{BCC} = 2 \times 0.2863^3 = 0.046935\, nm^3$$

$$V_{FCC} = 0.3591^3 = 0.046307\, nm^3$$

$$Volume\ Change = \frac{V_{FCC} - V_{BCC}}{V_{BCC}} = \frac{0.046307 - 0.046935}{0.046935} = -\ 0.0134 = -\ 1.34\,\%$$

II) Consider the engineering stress-engineering strain diagram for an aluminum alloy initially 11 mm in diameter and 50 mm in length, calculate the following (give your answer in metric unit):



a) the yield point assuming the 0.2% offset (8 points)

$$\sigma_{Yield} \approx 300\ MPa\ \ (See\ the\ diagram)$$

b) the elongation at fracture (4 points)

$$\epsilon_{Fracture} \approx 0.16\ \rightarrow\ Elongation = (50\ mm) \times (0.16) = 8\ mm$$

c) the true strain at an engineering strain of 0.05 (4 points)

$$\epsilon_{True} = ln(1 + \epsilon_{Eng}) = ln(1 + 0.05) = 0.04879$$

d) the elongation when a load of 25 kN is applied. (4 points)

$$\sigma_{(F = 25\,kN)} = \frac{25\,kN}{\pi \times 11^2 \times 0.25\,mm^2} = 263\,MPa < \sigma_{Yield}\ (Elastic\ region)$$

$$From\ small\ diagram \rightarrow \epsilon_{(\sigma = 263\,Mpa)} \approx 0.0045$$

(Alternatively, one may calculate elastic modulus and find the corresponding strain using it)

$$Elongation = (50\,mm) \times (0.0045) = 0.225\,mm$$

e) the plastic strain when the sample is unloaded after reaching a total engineering strain of 0.05 (4 points)

Find the elastic modulus from the elastic portion of the diagram:

(Using the results of the previous section, but any point in the elastic region is correct)

$$E = \frac{263\,MPa}{0.0045} = 58444\,MPa$$

$$At\ \epsilon = 0.05 \rightarrow \sigma \approx 350\,MPa \quad (From\ diagram)$$

Elastic recovery when unloaded at stress = 350 MPa:

$$\epsilon_{Elastic} = \frac{350}{58444} = 0.006$$

$$\epsilon_{Plastic} = \epsilon_{Total} - \epsilon_{Elastic} = 0.5 - 0.006 = 0.044$$

Question 3: (35 points)
Consider the steel phase diagram shown below:

I) How much iron does cementite contain? (5 points)

Cementite contains 6.67% Carbon and 100%-6.67%=93.33% Iron

II) What is the composition of ferrite at 800 C? (5 points)

In the austenite-ferrite region: get directly from the phase diagram or:

0.02% * (912-800)/(912-723) = 0.011%.

III) For a hypoeutectoid steel, what is the composition of austenite at 800 C? (5 points)

In the austenite-ferrite region: get directly from the phase diagram or:

0.8% * (912-800)/(912-723) = 0.474%.

IV) Compute the percentage of eutectoid Fe3C in eutectoid (α + Fe3C). (5 points)

Assuming 0.8% Wc and a temperature of 723C-ΔT:

W Fe3C: (0.8-0.02)/(6.67-0.02)=0.117 or 11.7%

V) At a temperature just below 723C, a hypoeutectoid steel contains 18% eutectoid ferrite. Compute the percentage of eutectoid cementite and proeutectoid ferrite. (15 points)

Finding first the average carbon content:

Total Ferrite=Proeutectoid Ferrite + Eutectoid ferrite

Proeutectoid Ferrite = Total Ferrite - Eutectoid ferrite

(0.8-X)/(0.8-0.02) = (6.67 -X)/(6.67-0.02) – 0.18

X= 0.179% Wc

Now, Proeutectoid Ferrite:
(0.8-0.179)/(0.8-0.02) =79.6%

Now, Eutectoid cementite:

(0.179-0.02)/(6.67-0.02) = 2.4%

Verifying just below 723C:

Proeutectoid ferrite + eutectoid ferrite + eutectoid cementite = 100%

79.6% + 18% + 2.4% = 100%