UNIVERSITY OF GHANA

FACULTY OF ENGINEERING SCIENCES
BSc. (ENG) MATERIALS SCIENCE AND ENGINEERING

First Semester Examinations: 2012/2013

MTEN 201: Fundamentals of Materials Science and Engineering (3 Credits)

Time Allowed: 3 Hours

Answer ALL questions in Section A & B

SECTION A: 30MARKS

1. Show that the atomic packing factor for Hexagonal closed–packed (HCP) is **0.74** **(2 marks)**
2. Prove that the lattice parameter or cubic edge length of a Body centered cubic (BCC) is given as $a = \frac{4R}{\sqrt{3}}$ as well as its atomic packing factor being **0.68.** **(2marks)**
3. The net potential energy between two adjacent ions E_N may be represented as

   $$E_N = -\frac{A}{r} + \frac{B}{r^n}$$ **(3marks)**

   Calculate the bonding energy E_0 in terms of A,B and n using the following procedure

   i. Differentiate E_N with respect to r, and set the resulting expression equal to zero. since the curve of E_N versus r is a minimum at E_0

   ii. Solve for r in terms of A, B and n which yields r_0, the equilibrium interionic-spacing

   iii. Determine the expression of E_0 by substitution of r_0 into the above equation
4. Draw the following crystallographic directions and planes **(5marks)**

   i. [1 0 1]

   ii. [1 $\bar{1}$ 1]

   iii. (1 $\bar{1}$ 0)

   iv. (2 $\bar{1}$ 0)

v. $(\bar{1}\,0\bar{1})$

5. Write the electronic configuration for the following atoms **(5marks)**
   - **a.** $_{18}$**Ar**
   - **b.** $_{26}$**Fe**
   - **c.** $_{24}$**Cr**
   - **d.** $_{29}$**Cu**
   - **e.** $_{21}$**Sc**
6. Define the following terms **(3marks)**
   a) Sintering
   b) Crystalline and amorphous solids
   c) Substitutional and interstitial solid solutions
7. Write the mathematical expressions for the Fick's first and second law and define the terms **(2marks)**
8. What is an isomophous system? **(3marks)**
9. Differentiate between point defects and line defects **(2marks)**
10. State the Bragg's law for X-ray diffraction. Using the Bragg equation and also given that the relation between the interplanar distance, ***d***, of a cubic structure and its lattice parameter, ***a***, is

$$d_{hkl} = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

Prove that **(3marks)**

$$a^2 = \frac{\lambda^2}{4\sin^2\theta}(h^2 + k^2 + l^2)$$

where n = 1

SECTION B 40MARKS

1. A plate of iron is exposed to a carburizing atmosphere on one side and decarburing atmosphere on the other side at 700°C. If conditions of steady are achieved, calculate the diffusion flux of carbon through the plate if the concentrations of carbon at positions of 5 and 10 mm beneath the carburizing surface are 1.2 and 0.8 kg/m^3, respectively. Assume a diffusion coefficient of $3x10^{-11}$ m^2/s at this temperature. **(10marks)**

2. (i) A common question asked by most Materials Engineers is, why the need to steady Phase Diagrams. Briefly explain the need to study phase diagrams. **(2marks)**

   (ii) What is the difference between a binary isomorphous and eutectic phase diagrams by considering also the elements involved. **(3marks)**

Solders are metal alloys that are used to bond or join two or more components. Majority of solders are Pb-Sn alloys and these materials are reliable, inexpensive and have low melting points. The most common Pb-Sn solder has a composition of 63wt%Sn – 37wt% Pb as seen in figure 1.

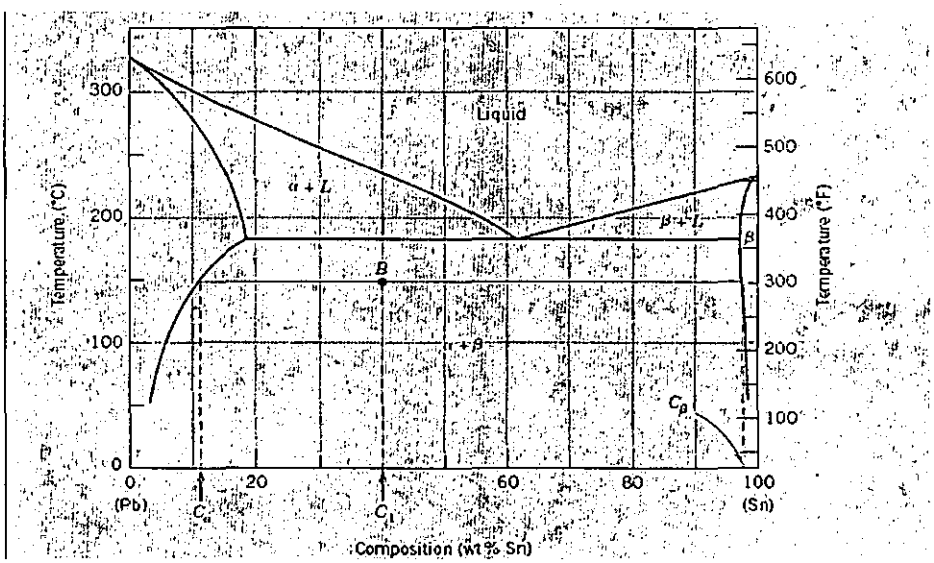

Figure 1: Lead-Tin Phase Diagram

For a 40%wtSn-60%wtPb alloy at 150°C

(iii) What phase(s) is (are) present? **(5marks)**

(iv) What is (are) the composition(s) of the phase (s) **(5marks)**

3. X-rays are important for the study of crystal structure and the development of new materials. In a given crystal structure analysis, it is revealed that BCC Fe has a lattice parameter of 0.2866nm. Compute the

(a) Inter planar spacing **(2 marks)**

(b) The diffraction angle for the (220) set of planes **(3 marks)**

Assume a monochromatic radiation with wavelength 0.179nm is used and the order of reflection "n" is 1.

(c) Magnesium has an HCP crystal structure, a c/a ratio of 1.62 and a density of 1.74g/cm^3. Compute the atomic radius of magnesium. **(10marks)**