UNIVERSITY OF GHANA

BSC. ENGINEERING FIRST SEMESTER EXAMINATIONS: 2016/2017

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

MTEN 201: FUNDAMENTALS OF MATERIALS SCIENCE AND ENGINEERING

(3 CREDITS)

INSTRUCTIONS: ANSWER ALL QUESTIONS IN SECTION A, ANY TWO QUESTIONS FROM SECTION B AND ONE QUESTION FROM SECTION C.

TIME ALLOWED: THREE HOURS

SECTION A
ANSWER ALL QUESTIONS FROM THIS SECTION

1. Name the following phase transformations:

- **a.** Vapor → Liquid
- **b.** Liquid → Vapor
- **c.** Vapor → Solid
- **d.** Solid → Vapor
- **e.** Liquid → Solid
- **f.** Solid → Liquid
- **g.** Solid → Solid
- **h.** Liquid → Solid (1) + Solid (2)
- **i.** Liquid + Solid (1) → Solid (2)
- **j.** Liquid (1) + Liquid (2) → Solid
- **k.** Solid → Solid (1) + Solid (2)
- **l.** Solid (1) → Solid (2) (diffusionless)
- **m.** Solid (1) → Solid (2) (diffusion controlled)

(13 marks)

2. The **table-1** below is a list of materials. Classify each of them according to their crystal structures at room temperature.

Table-1

Aluminium	Copper	Lead	Gold	Silver
Chromium	Tungsten	Magnesium	Vanadium	Tantalum
Iron	Tin (gray)	Silicon	Rhenium	Ruthenium
α-Polonium	Germanium	Zirconium	Arsenic	Antimony
	Bismuth	Selenium	Zinc	Boron

(24 marks)

3. Using concepts associated with phases and microstructure, distinguish between the following;

- **a.** austenite and ferrite
- **b.** pearlite and bainite
- **c.** martensite and tempered martensite
- **d.** homogeneous and heterogeneous nucleation

(8 marks)

4. The first eight planes which give the x-ray diffraction peaks for aluminium are given below. In your answer for questions (a) and (b) use a separate sketch for each plane and direction of the unit cell.

a. Sketch each plane relative to the FCC unit cell and emphasize atom positions within the planes.

   i. (111)
   ii. (200)
   iii. (220)
   iv. (311)
   v. (222)
   vi. (400)
   vii. (331)
   viii. (420)

(16 marks)

b. Also sketch the following directions within the unit cell.

   i. $[101]$
   ii. $[0\bar{1}0]$
   iii. $[12\bar{2}]$
   iv. $[301]$
   v. $[\bar{2}01]$
   vi. $[2\bar{1}3]$
   vii. $[410]$
   viii. $[111]$

(16 marks)

5. Determine the planar density and the packing fraction for FCC Nickel in the (100), (110) and (111) planes. Which, if any of these planes is closed packed?

(12 marks)

6. Determine the planar density and the packing fraction for BCC lithium in the (100), (110) and (111) planes. Which, if any of these planes is closed packed?

(12 marks)

7. The **table-2** below shows the results of an x-ray diffraction experiment for a pure crystalline cubic material. If x-rays with a wavelength of 1.54056Å are used, determine,

a. The crystal structure of the material.

b. The indices of the planes that produce each of the peaks.

c. The lattice parameter of the materials.

Table-2

2θ (deg)	d-spacing (Å)
38.493	2.34
55.594	1.65
69.669	1.35
82.541	1.17
95.009	1.05
107.791	0.953

(12 marks)

8. Nucleation and solidification of melt are mostly considered for a spherical geometry of the nucleus for practical purposes.

   a. Write an expression for the total free energy change for nucleation for the case of a cubic nucleus of edge length a, instead of a sphere of radius r.
   b. Now differentiate your expression in **(a)** with respect to a and solve for both the critical cube edge length, a^*, and ΔG^*. What is the significance of a^* and ΔG^* which you have obtained.
   c. Is ΔG^* greater for a cube or a sphere? Why?

(12 marks)

SECTION B
ANSWER ANY TWO QUESTIONS FROM THIS SECTION

9. Electronic devices such as transistors are made by doping semiconductors. The diffusion coefficient of phosphorus (P) in silicon (Si) is $D = 6.5\times10^{-13}$ cm^2/s at a temperature of 1100 °C. Assume the source provides a surface concentration of 10^{20} atoms/cm^3 and the diffusion time is one hour. Assume that the silicon wafer initially contains no P. Calculate the depth at which the concentration of P will be 10^{18} atoms/cm^3. State any assumptions you have made while solving this problem. Find attached an error function **table-3.**

(10 marks)

10. The alpha phase of manganese which is, α-Mn has a cubic structure with $a_0 = 0.8931$ *nm* and density of 7.470 g/cm^3. The beta form which is β-*Mn*, has a different cubic structure with $a_0 = 0.6326$ *nm* and density of 7.260 g/cm^3. The atomic weight of manganese is 54.938 *g/mol* and the atomic radius is 0.112 *nm*. Determine the percentage volume change if α-Mn transforms to β-Mn.

(10 marks)

11. Gallium has an orthorhombic crystal structure, with $a_0 = 0.45258$ *nm*, $b_0 = 0.45186$ *nm* and c_0=0.76570 *nm*. The atomic radius is 0.1218 *nm*. The density is 5.904 *g/cm^3*, and the atomic weight is 69.72 *g/mol*. The volume of the orthorhombic unit cell, $V = abc$, where a, b and c are the dimensions of the orthorhombic lattice geometry.

   a. Determine the number of atoms in the unit cell.
   b. The packing factor in the unit cell.

(10 marks)

12. Indium has a tetragonal crystal structure with $a = 0.32517$ *nm* and $c = 0.49459$ *nm*. The density is 7.286 *g/cm^3* and the atomic weight is 114.82 *g/mol*. The volume of the tetragonal unit cell, $V = a^2c$, where a and c are the dimensions of the tetragonal lattice geometry. Based on the information given does indium have the simplest tetragonal or body-centered tetragonal structure?

(10 marks)

SECTION C
ANSWER ONLY ONE QUESTION FROM THIS SECTION

13. The **figure-1** below is the phase diagram for copper (Cu) and silver (Ag). Considering For 40 wt% of Ag at 779 °C, determine the following;

a. The phases present and the phase compositions.

b. The relative amount of each phase.

c. Considering a fixed composition 71.9 *wt* % of Ag, draw the microstructure at 1000 °C, 700 °C, 400 °C and 25 °C.

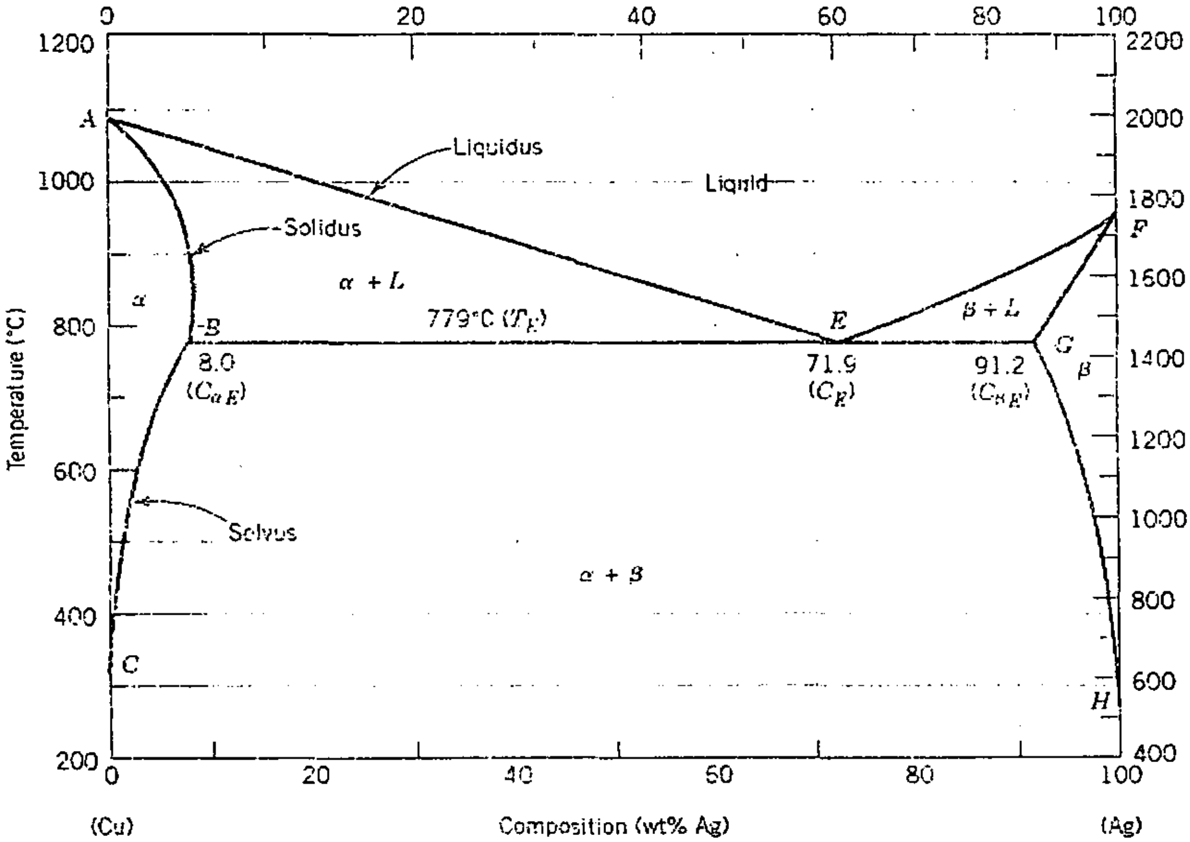

Figure 1

(15 marks)