UNIVERSITY OF GHANA

BSC. ENGINEERING

DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING

MTEN 201: FUNDAMENTALS OF MATERIALS SCIENCE AND ENGINEERING

(3 CREDITS)

FIRST SEMESTER EXAMINATION: 2018/2019

INSTRUCTIONS

Attached are an error function data (see table-1) and a formula sheet

ANSWER ALL QUESTIONS TIME: THREE (3) HOURS

1. With the help of schematics, equations and examples where necessary, distinguish between the following pairs of terms:
   (i) Allotropy and polymorphism
   (ii) Face centered cubic (FCC) and hexagonal close packed (HCP) structures
   (iii) Polystyrene (PS) and poly-methyl-methacrylate (PMMA)
   (iv) Engineering stress and true stress
   (v) Eutectic and eutectoid reaction
   (vi) Isotacticity and syndiotacticity
   (vii) Covalent bonding and ionic bonding
   (viii) Atomic packing factor and coordination number
   (ix) Plastic deformation and elastic deformation
   (x) Grain and grain boundary

(10 marks)

2.
   (a) Sketch each plane relative to the cubic unit cell and emphasize atom positions within the planes.
   (i) (111) **(ii)** (222) **(iii)** (311) **(iv)** (200) **(v)** (420) **(vi)** (220)

   (b) Also sketch the following directions within the unit cell.
   (i) [101] **(ii)** $[\bar{2}01]$ **(iii)** $[0\bar{1}0]$ **(iv)** $[2\bar{1}3]$ **(v)** $[12\bar{2}]$ **(vi)** [410]

   In your answer for questions **(a)** and **(b)** use a separate sketch for each plane and direction of the unit cell. **(12 marks)**

3. Give a full and well labelled sketch for an engineering stress-strain curve for a typical metallic material. **(6 marks)**

4. The below is a list of materials. What would be their crystal structures at room temperature?
   (i) Germanium **(ii)** Tungsten **(iii)** Bismuth **(iv)** Gold **(v)** Magnesium **(vi)** Copper

(6 marks)

5. Describe in your own words the three strengthening mechanisms (i.e., grain size reduction, solid-solution strengthening, and strain hardening). Be sure to explain how dislocations are involved in each of the strengthening techniques.

(10 marks)

6. Calculate the number of vacancies per cubic meter in iron at 855 °C. The energy for vacancy formation is 1.08 eV/atom. Furthermore, the density and atomic weight for Fe are 7.65 g/cm^3 and 55.85 g/mol, respectively. Take the Boltzmann constant to be 8.62×10^{-5} eV/atom K and Avogadro's number to be 6.02×10^{23} atoms/mole.

(6 marks)

7. A cylindrical specimen of a titanium alloy having an elastic modulus of 108 GPa and an original diameter of 3.9 mm will experience only elastic deformation when a tensile load of 2000 N is applied. Compute the maximum length of the specimen before deformation if the maximum allowable elongation is 0.42 mm.

(6 marks)

8. A diffracted x-ray beam is observed from the (220) planes of iron at a 2θ angle of 99.1° when x-rays of 0.15418 *nm* wavelength is used. Calculate the lattice parameter of the iron.

(4 marks)

9. Polypropylene forms an orthorhombic unit cell with lattice parameters of $a_o = 1.450$ nm, $b_o = 0.569$ nm, and $c_o = 0.740$ nm. The chemical formula for the propylene molecule, from which the polymer is produced, is C_3H_6. The density of the polymer is about 0.90 g/cm^3 and the volume is expressed as, $V = a_o \times b_o \times c_o$. Determine,
   (a) the number of propylene molecules in each unit cell
   (b) the number of carbon atoms in each unit cell
   (c) the number of hydrogen atoms in each unit cell.

(8 marks)

10. An FCC iron–carbon alloy initially containing 0.35 wt% C is exposed to an oxygen-rich and virtually carbon-free atmosphere at 1127 °C. Under these circumstances the carbon diffuses from the alloy and reacts at the surface with the oxygen in the atmosphere; that is, the carbon concentration at the surface position is maintained essentially at 0 wt% C. (This process of carbon depletion is termed *decarburization*.) At what position will the carbon concentration be 0.15 wt% after a 10-h treatment? The value of D at 1127 °C is 6.9×10^{-11} m^2/s.

(8 marks)

11. Some aircraft component is fabricated from an aluminum alloy that has a plane strain fracture toughness of 40 MPa$\sqrt{m}$. It has been determined that fracture results at a stress of 300 MPa when the maximum (or critical) internal crack length is 4.0 mm. For this same component and alloy, will fracture occur at a stress level of 260 MPa when the maximum internal crack length is 6.0 mm? Why or why not?

(8 marks)

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

(a) Determine 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 the following temperatures;
(i) 1000 °C
(ii) 700 °C
(iii) 400 °C
(iv) 25 °C.

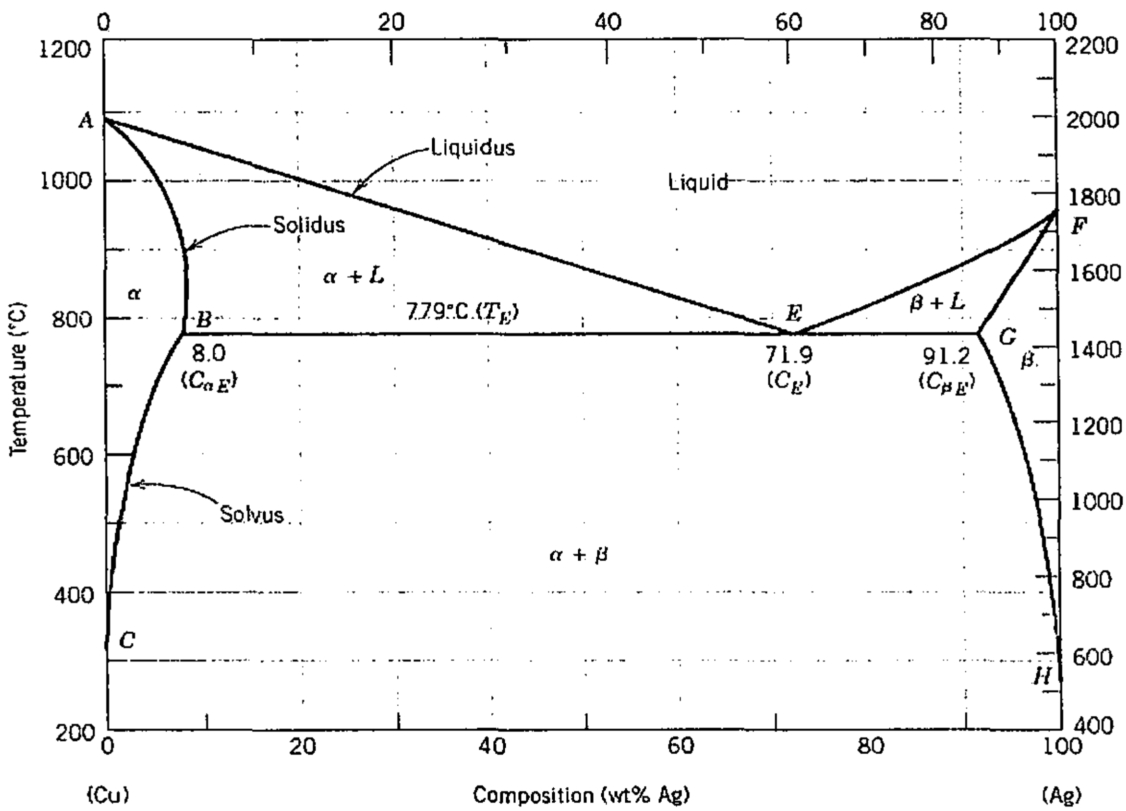

Figure-1: Copper (Cu)-Silver (Ag) phase diagram

(16 marks)

Table-1: Error function table

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

Formula Table

(All terms have their usual meanings and as used in class)

$$\frac{N_v}{N} = \exp\left(-\frac{Q_v}{kT}\right) \qquad M = JAt = -DAt\frac{\Delta C}{\Delta x} \qquad J = -D\frac{\Delta C}{\Delta x}$$

$$D = D_0 \exp\left(-\frac{Q_d}{RT}\right) \qquad \frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} \qquad \frac{C_x - C_0}{C_s - C_0} = 1 - \operatorname{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

$$\sigma_m = 2\sigma_0\left(\frac{a}{\rho_t}\right)^{1/2} \qquad \sigma_c = \left[\frac{2E\gamma_s}{\pi a}\right]^{1/2} \qquad \sigma_c = \frac{K_{Ic}}{Y\sqrt{\pi a}}$$

Best wishes and happy New Year!