# UNIVERSITY OF GHANA



**BSC. ENGINEERING FIRST SEMESTER EXAMINATIONS: 2017/2018**
**DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING**
**MTEN 201: FUNDAMENTALS OF MATERIALS SCIENCE AND ENGINEERING**
**(3 CREDITS)**

INSTRUCTIONS: ANSWER ALL QUESTIONS IN SECTION A, TWO QUESTIONS (QUESTION 12 AND ANY OTHER) FROM SECTION B AND ONE QUESTION FROM SECTION C.

TIME ALLOWED: THREE (3) HOURS

SECTION A
ANSWER ALL QUESTIONS FROM THIS SECTION

**1.** Classify the following materials into the major heading as metals, ceramics, polymers or composites.

**(a).** niobium
**(b).** silica ($SiO_2$)
**(c).** polyethylene
**(d).** silicon carbide (SiC)
**(e).** wood
**(f).** nylon
**(g).** silicon nitride ($Si_3N_4$)
**(h).** alumina ($Al_2O_3$)
**(i).** bronze
**(j).** cotton
**(k).** cemet
**(l).** palladium

*(6 marks)*

**2.** 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)

*(6 marks)*

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

**Table-1**

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

*(10 marks)*

5. **(a).** Briefly cite the main differences between ionic, covalent, and metallic bonding.
**(b).** State the Pauli Exclusion Principle.

*(7 marks)*

4. (a). Briefly describe the microstructural difference between spheroidite and tempered martensite.

(b). Explain why tempered martensite is much harder and stronger.

(c). Briefly explain why fine pearlite is harder and stronger than coarse pearlite, which in turn is harder and stronger than spheroidite.

Supporting your answer with a microstructural sketch is recommended.

**(8 marks)**

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

| | | |
|---|---|---|
| **(a).** (111) | **(b).** (222) | **(c).** (400) |
| **(d).** (200) | **(e).** (400) | **(f).** (220) |
| **(g).** (331) | **(h).** (420) | |

*(8 marks)*

Also sketch the following directions within the unit cell.

| | | |
|---|---|---|
| **(a).** [101] | **(b).** $[\bar{2}01]$ | **(c).** $[0\bar{1}0]$ |
| **(d).** $[2\bar{1}3]$ | **(e).** $[12\bar{2}]$ | **(f).** [410] |
| **(g).** [301] | **(h).** [111] | |

In your answer for questions **(a)** and **(b)** use a separate sketch for each plane and direction of the unit cell. *(8 marks)*

7. 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?

*(8 marks)*

8. A diffracted x-ray beam is observed from the (220) planes of iron at a $2\theta$ angle of $99.1^{\circ}$ when x-rays of 0.15418 *nm* wavelength are used. Calculate the lattice parameter of the iron.

*(6 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$^3$. 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. 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 $\Delta G^*$. What is the significance of $a^*$ and $\Delta G^*$ which you have obtained.

**(c).** Is $\Delta G^*$ greater for a cube or a sphere? Why?

*(10 marks)*

11. The net potential energy between two adjacent ions may be represented the equation;

$$E_N = -\frac{A}{r} + \frac{B}{r^n} \qquad (10.1)$$

Calculate the bonding energy in terms of the parameters $A$, $B$, and $n$ using the following procedure:

(a). Differentiate with respect to $r$ and then set the resulting expression equal to zero, since the curve of versus r is a minimum at $E_O$.

(b). Solve for r in terms of $A$, $B$, and $n$, which yields the equilibrium interionic spacing.

(c). Determine the expression for by substitution of into equation (10.1). ***(10 marks)***

## SECTION B
## ANSWER QUESTION 12 AND ANY OTHER QUESTION FROM THIS SECTION

12. The following data (table 12.1) and plot (figure 12.1) were collected from a 0.4-in. diameter test specimen of polyvinyl chloride ($l_o = 2.0$ in.).

**Table 12.1**

| Load (lb) | Gage Length (in.) | Stress (psi) | Strain (in./in.) |
|---|---|---|---|
| 0 | 2.00000 | 0 | 0.0 |
| 300 | 2.00746 | 2,387 | 0.00373 |
| 600 | 2.01496 | 4,773 | 0.00748 |
| 900 | 2.02374 | 7,160 | 0.01187 |
| 1200 | 2.032 | 9,547 | 0.016 |
| 1500 | 2.046 | 11,933 | 0.023 |
| 1660 | 2.070 (max load) | 13,206 | 0.035 |
| 1600 | 2.094 | 12,729 | 0.047 |
| 1420 | 2.12 (fracture) | 11,297 | 0.06 |

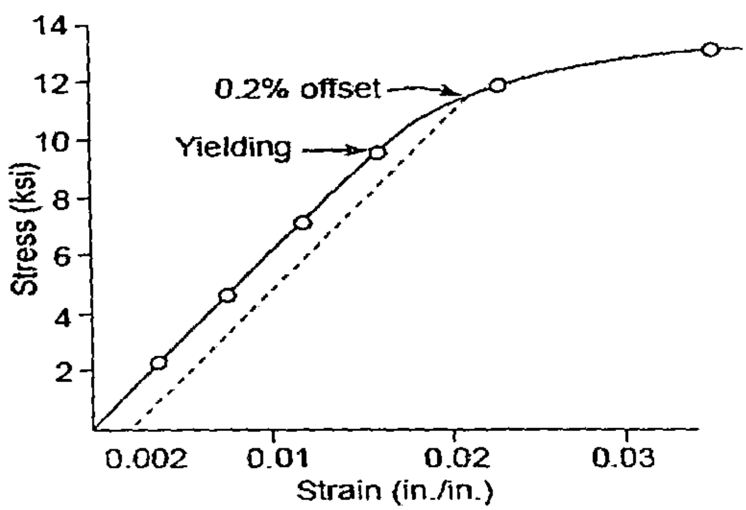


**Figure 12.1**

After fracture, the gage length is 2.09 in. and the diameter is 0.393 in. Calculate

a. the 0.2% offset yield strength
b. the tensile strength
c. the modulus of elasticity
d. the % elongation
e. the % reduction in area
f. the engineering stress at fracture
g. the true stress at fracture
h. the modulus of resilience.

*(16 marks)*

13. A sheet of steel 2.5 mm thick has nitrogen atmospheres on both sides at C and is permitted to achieve a steady-state diffusion condition. The diffusion coefficient for nitrogen in steel at this temperature is $1.2 \times 10^{-10}$ $m^2/s$, and the diffusion flux is found to be $kgm^{-2}s^{-}1$. Also, it is known that the concentration of nitrogen in the steel at the high-pressure surface is 2 $kgm^{-3}$. How far into the sheet from this high pressure side will the concentration be 0.5 $kgm^{-3}$? Assume a linear concentration profile. Find attached an error function table **(table-13.1)** .

*(10 marks)*

14. 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?

*(10 marks)*

**SECTION C**
**ANSWER ONLY ONE QUESTION FROM THIS SECTION**

15. The figure-15.1 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.

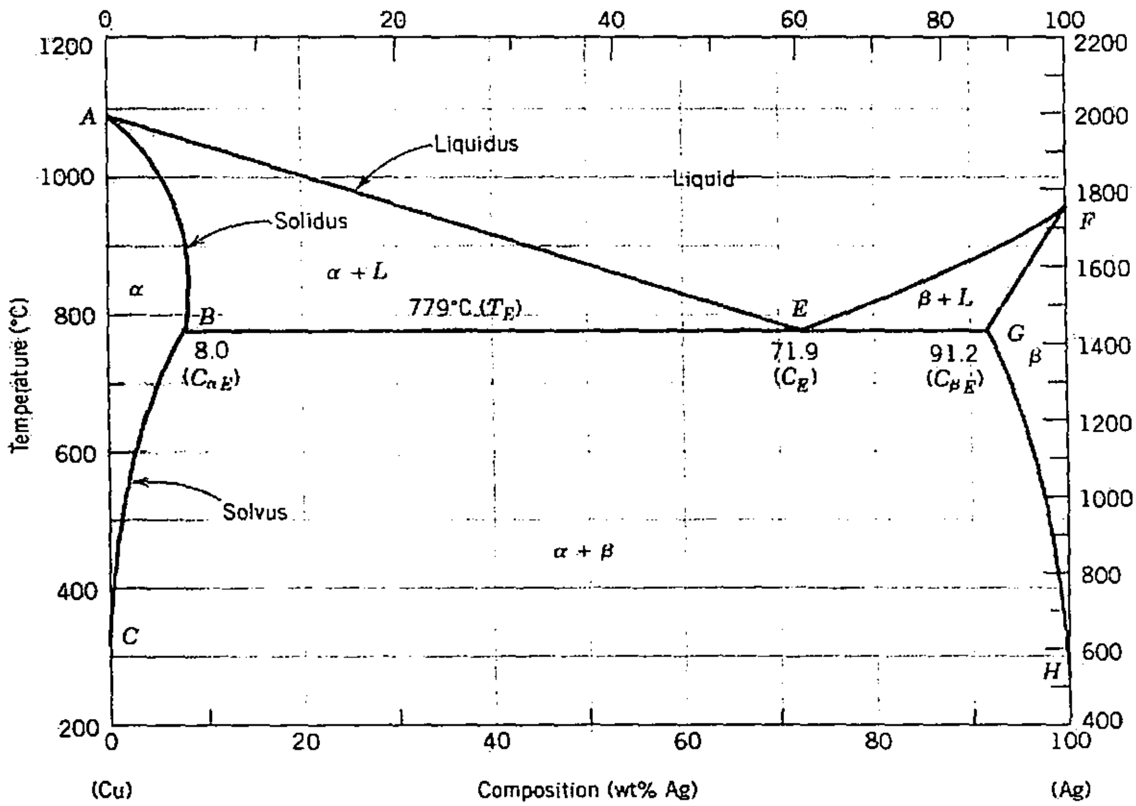


**Figure 15.1**

*(15 marks)*

16. Figure 16.1 is the aluminum–neodymium phase diagram, for which only single-phase regions are labeled. Specify temperature-composition points at which all eutectics, eutectoids, and peritectics phase transformations occur. Also, for each, write the reaction upon cooling.

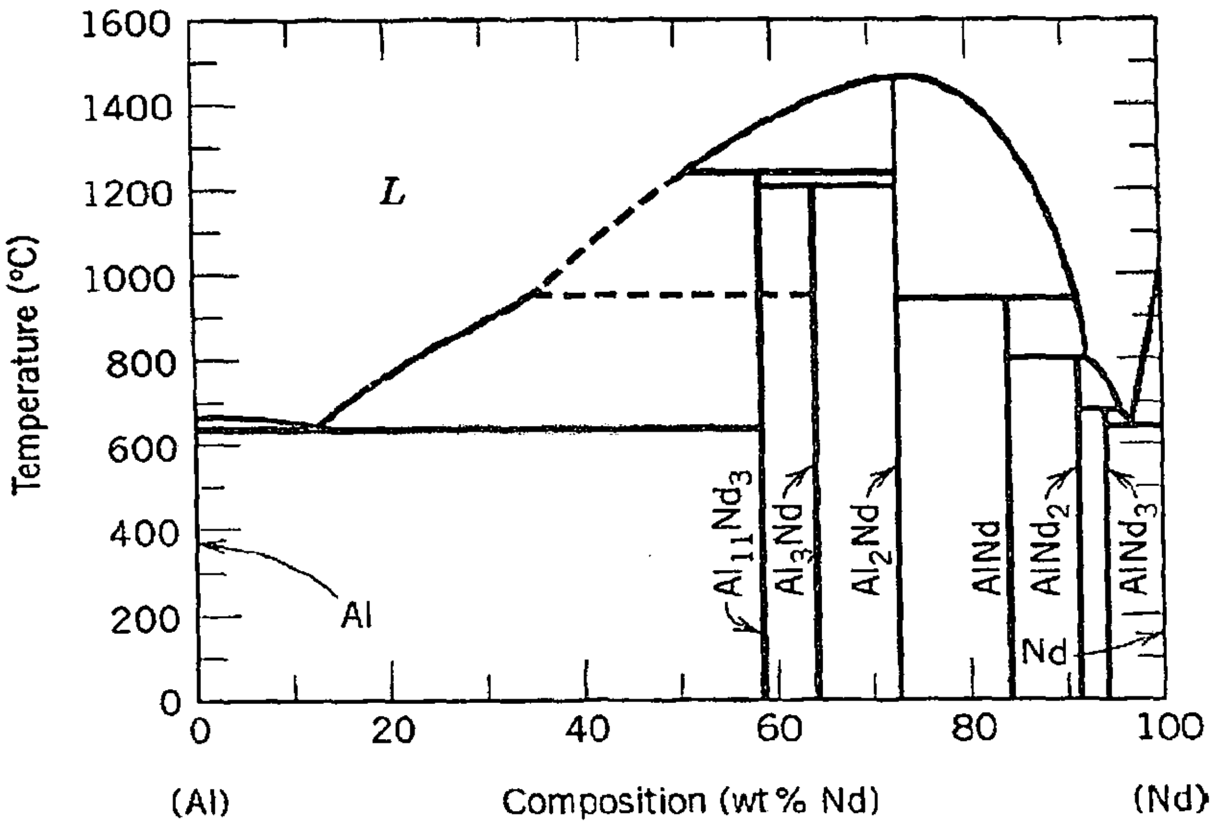


**Figure 16.1**

*(15 marks)*

## ERROR FUNCTION TABLE

**Table-13.1**

| $z$ | $erf(z)$ | $z$ | $erf(z)$ | $z$ | $erf(z)$ |
|---|---|---|---|---|---|
| 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 |

**Best wishes and happy New Year!**