# FACULTY OF ENGINEERING AND ENVIRONMENT

## DEPARTMENT METALLURGICAL ENGINEERING

## ENGINEERING MATERIALS

## EMR 1204

## Final Examination Paper

## AUGUST 2022

This examination paper consists of 6 pages

**Time Allowed:** **3 hours**

**Total Marks:** **100**

**Examiner's Name:** **MR O D CHIKATI**

**Instructions**

1. Answer all questions in Section A and any 2 Questions from Section B.
2. Each question carries 20 marks.
3. Use of calculators is permissible.

**Additional Requirements**

Calculator
Periodic Table of Elements

**Mark Allocation**

| | |
|---|---|
| Part Questions | As shown in each part question. |
| Total Attainable | 100 |

**SECTION A:** *answer all questions*

**QUESTION A1**

a) With the aid of neat sketches describe the bonding in:

(i) Copper and explain why copper is a good conductor of electricity**. [4 Marks]**

(ii) Magnesium oxide and explain why magnesium oxide is an insulator. **[4 Marks]**

(iii) PVC and explain why PVC is an insulator. **[4 Marks]**

b) Give the electronic configuration of Cu and Mg atoms given atomic numbers for Cu and Mg to be 29 and 12 respectively. **[4 Marks]**

c) Calculate the interplanar spacing for an aluminium of atomic radius of 0,1431nm for the (110) set of planes. **[4 Marks]**

**QUESTION A2**

a) Briefly explain the working principles of the Scanning Electron Microscopy **[3 marks]**

b) Calculate the volume of an FCC unit cell in terms of the atomic radius R. **[4 marks]**

c) Show that the atomic packing factor for the FCC crystal structure is 0.74. **[4 marks]**

d) Define anisotropy**.** **[2 marks]**

e) Given that the lattice parameter of FCC copper is 0.36151 nm. Calculate the concentration of vacancies in copper at room temperature (25$^{o}$C). What temperature will be needed to heat treat copper such that the concentration of vacancies produced will be 1000 times more than the equilibrium concentration of vacancies at room temperature? Assume that 20,000 cal are required to produce a mole of vacancies in copper. [**7marks**]

**QUESTION A3**

a) State the three major reasons why hardness tests are performed more frequently than any other mechanical tests. **[3 marks]**

b) Explain giving examples how the following factors that affect corrosion of metals:

(i) Temperature **[4 Marks]**

(ii) Heat Treatment **[4 Marks]**

(iii) Stress **[4 Marks]**

(c) Draw the electrochemical corrosion circuit and label. **[5] Marks**

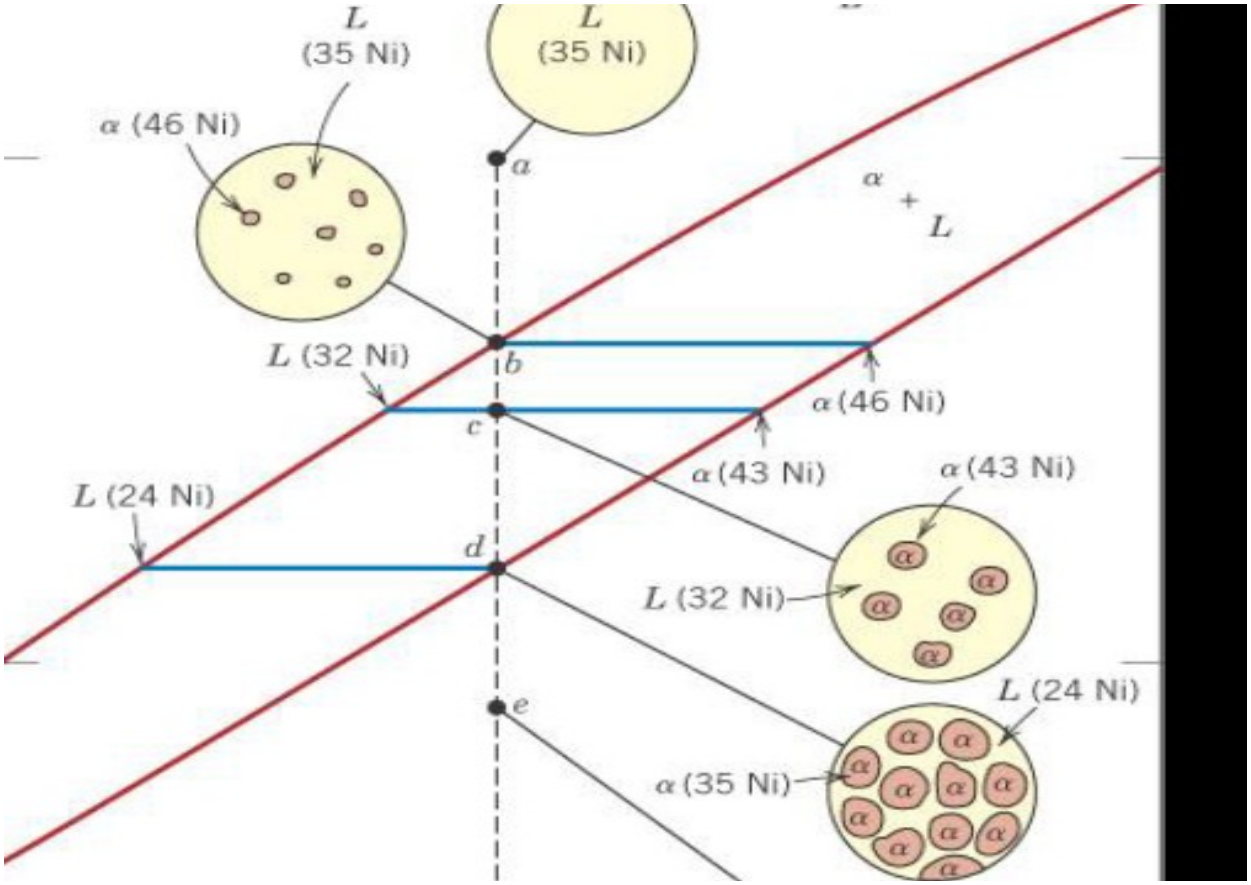
**SECTION B:** ***answer any 2 questions***

**QUESTION B1**

a) Define what a eutectic mixture is. [2]

b) Derive the Lever rule. [8]

c) Fig 1 shows what happens during cooling from high temperature (liquid) to room temperature (solid) for a Cu-Ni system. Describe the process. [10]



**QUESTION B2**

b) Briefly explain the concept of plastic deformation from an atomic perspective.

**[3 marks]**

c) A piece of copper originally 305 mm long is pulled with a stress of 276 MPa. If the deformation is entirely elastic and the magnitude of *E* for copper is 110 GPa, calculate the resultant elongation. **[3 marks]**

d) Safe stress (or working stress) is based on the yield strength of the material and is defined as the yield strength divided by a factor of safety, N.

i. State any three (3) important selection criteria for the value of N in engineering design problems. **[3 marks ]**

ii. Discuss the effects of choosing an inappropriate value of N**. [2 marks**]

e) Briefly describe the following modes of failure in materials:

i. Fracture **[3 marks ]**

ii. Fatigue **[3 marks ]**

iii. Creep **[3 marks ]**

**QUESTION B3**

a) Atomic radius, crystal structure, electronegativity, and the most common valences for several elements are tabulated in ***Table 1***. For those that are nonmetals, only atomic radii are indicated.

*Table 1 (Extracted from Materials Science and Engineering by D. Callister)*

| *Element* | *Atomic Radius (nm)* | *Crystal Structure* | *Electro-negativity* | *Valence* |
|---|---|---|---|---|
| Ni | 0.1246 | FCC | 1.8 | +2 |
| C | 0.071 | | | |
| H | 0.046 | | | |
| O | 0.060 | | | |
| Ag | 0.1445 | FCC | 1.9 | +1 |
| Al | 0.1431 | FCC | 1.5 | +3 |
| Co | 0.1253 | HCP | 1.8 | +2 |
| Cr | 0.1249 | BCC | 1.6 | +3 |
| Fe | 0.1241 | BCC | 1.8 | +2 |
| Pt | 0.1387 | FCC | 2.2 | +2 |
| Zn | 0.1332 | HCP | 1.6 | +2 |

Write down the elements you would expect to form the following with nickel:

i. A substitutional solid solution having complete solubility. **[2 marks]**

ii. A substitutional solid solution of incomplete solubility. **[2 marks]**

iii. An interstitial solid solution. **[2 marks]**

b) Barium at 20oC is BCC and has a lattice constant of 0.5019 and an interatomic distance of 0.218nm. Calculate the following:

(i) The atomic radius of Barium atoms. **[4 marks]**

(ii) Show with all the necessary steps that the atomic packing factor (AFP) in a BCC arrangement is 68%. **[8 marks]**

(d) What do you understand by the term allotrophic transformation**?** **[2 marks]**